Sustainable Data Evolution Technology (SDET) for Power Grid Optimization

presented by

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Project Summary

- Objective: to deliver large-scale, realistic, **evolvable** datasets and data creation tools for optimization problems such as AC OPF and VVO
  - Derive data features/metrics for real T+D systems
  - Develop tools to generate large-scale, open-access, realistic synthetic datasets
  - Validate the created datasets using industry tools
  - Integrate with GRID DATA repositories
- Timeline: October 2016 - September 2018

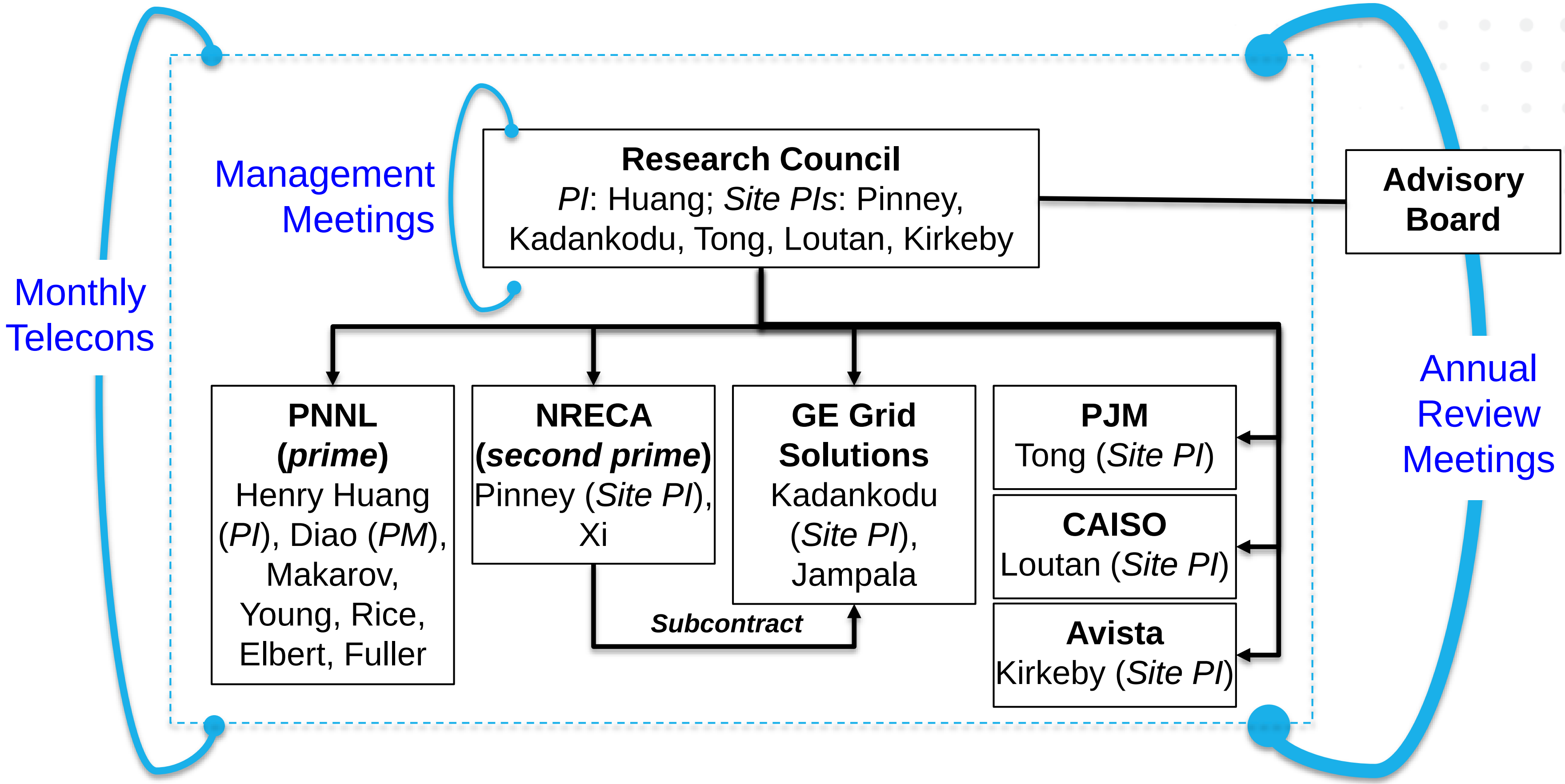
Evolvable open-access large-scale datasets to accelerate the development of next-generation power grid optimization.

Project Impact

- A novel concept "***data evolution***", with long-lasting impact
  - Disrupt the current ad hoc cycles of static dataset generation.
  - Enable the datasets to evolve with the increasing grid complexity.
  - Accelerate development and adoption of grid optimization methods.
  - Improve the reliability, resiliency and efficiency of the power grid.

Attributes	State of the Art	Proposed SDET
Size	<10,000 buses	>100,000 buses
Completeness	Missing information	100% support of AC-OPF,VVO
Number of contingencies	Few	>10,000
Number of scenarios	Few	>10,000
Data configurability	None to very limited	Configurable
Data evolvability	No	Evolvable

Team Organization



Capabilities, Facilities, Equipment, Information

- PNNL EIOC
  - Modeling, simulation and data host for Pacific Northwest Smart Grid Demonstration
  - PMU streams from Western Interconnect
  - Alstom/GE E-terra Platform
- PNNL Institutional Computing (PIC)
  - HPC platform with ~23K cores
- NRECA OMF: production system and user community
- GE Grid Solutions EMS/DMS Tools
- Available datasets (T+D models, Market data) and industry experience at NRECA, PJM, CAISO, and Avista
- Natural connection to one data repository team through personnel and facility

Pacific Northwest NATIONAL LABORATORY

NRECA A Touchstone Energy Cooperative

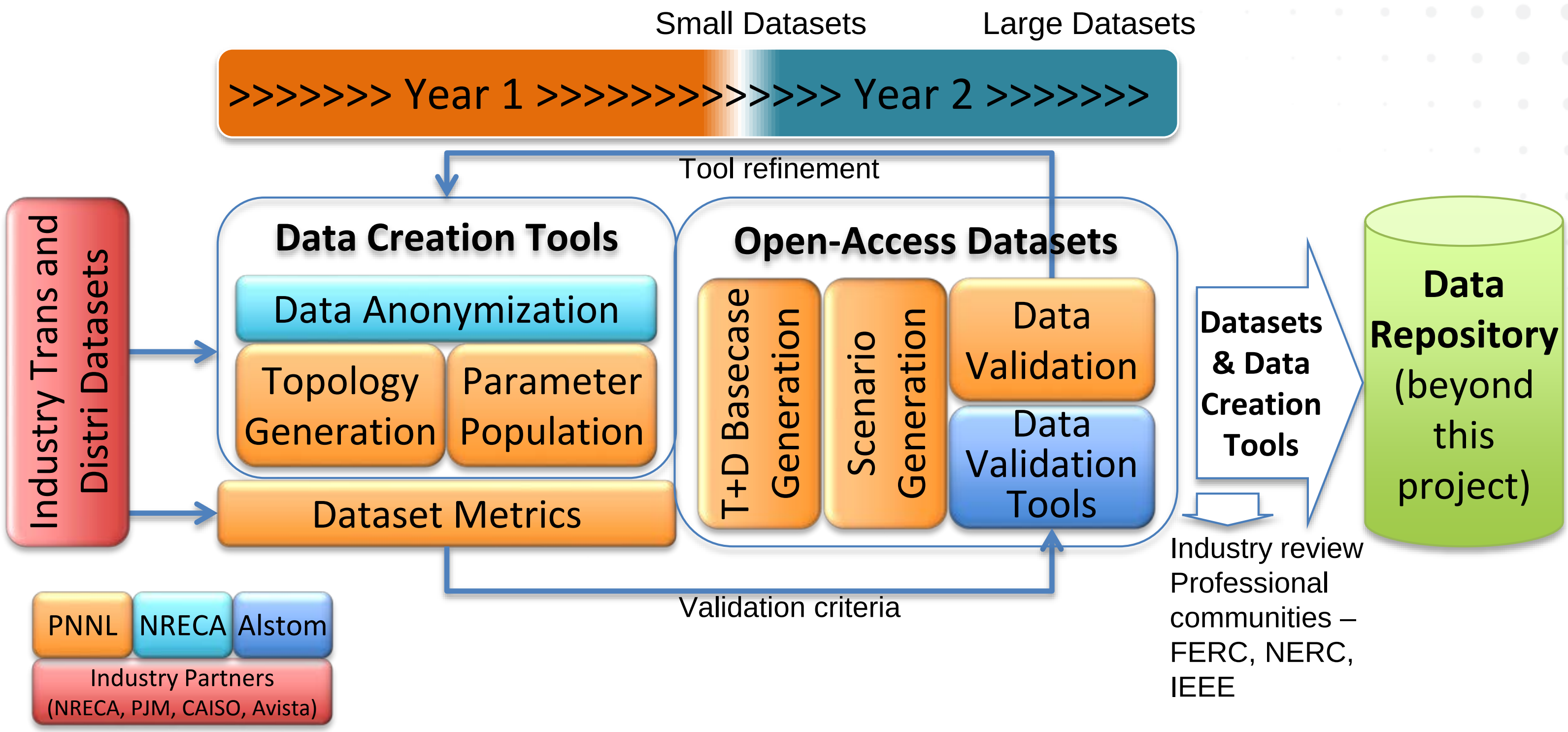
pjm

AVISTA

California ISO

GridLAB-D

Tasks and Dependency



Datasets Requirements

- Large-scale
- Realistic
- Open-access
- Sustainable (ARPA-E independent)
- Evolvable (datasets are not static)

Deliverables

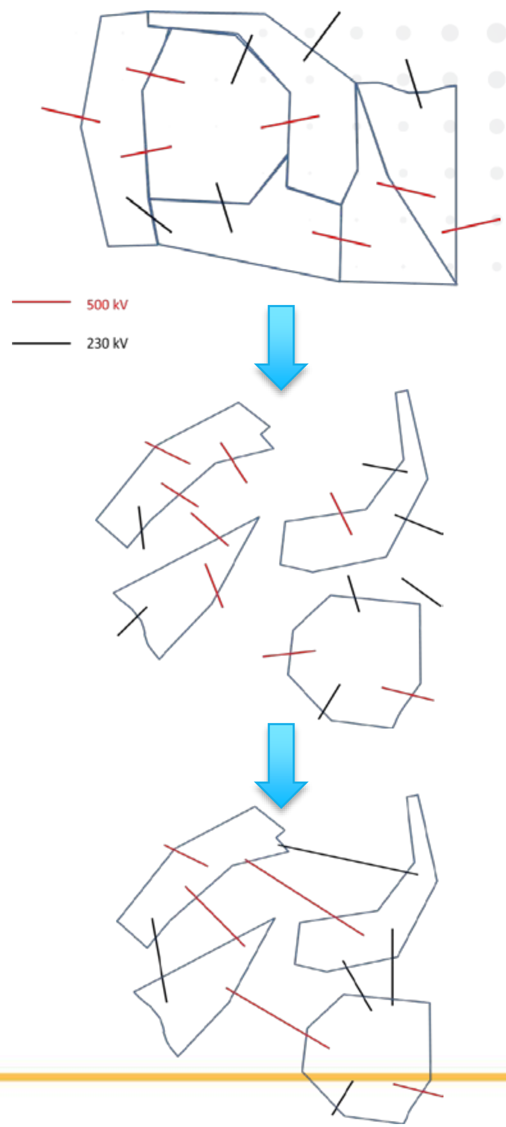
- Datasets
- Dataset creation tools

Proposed Technologies

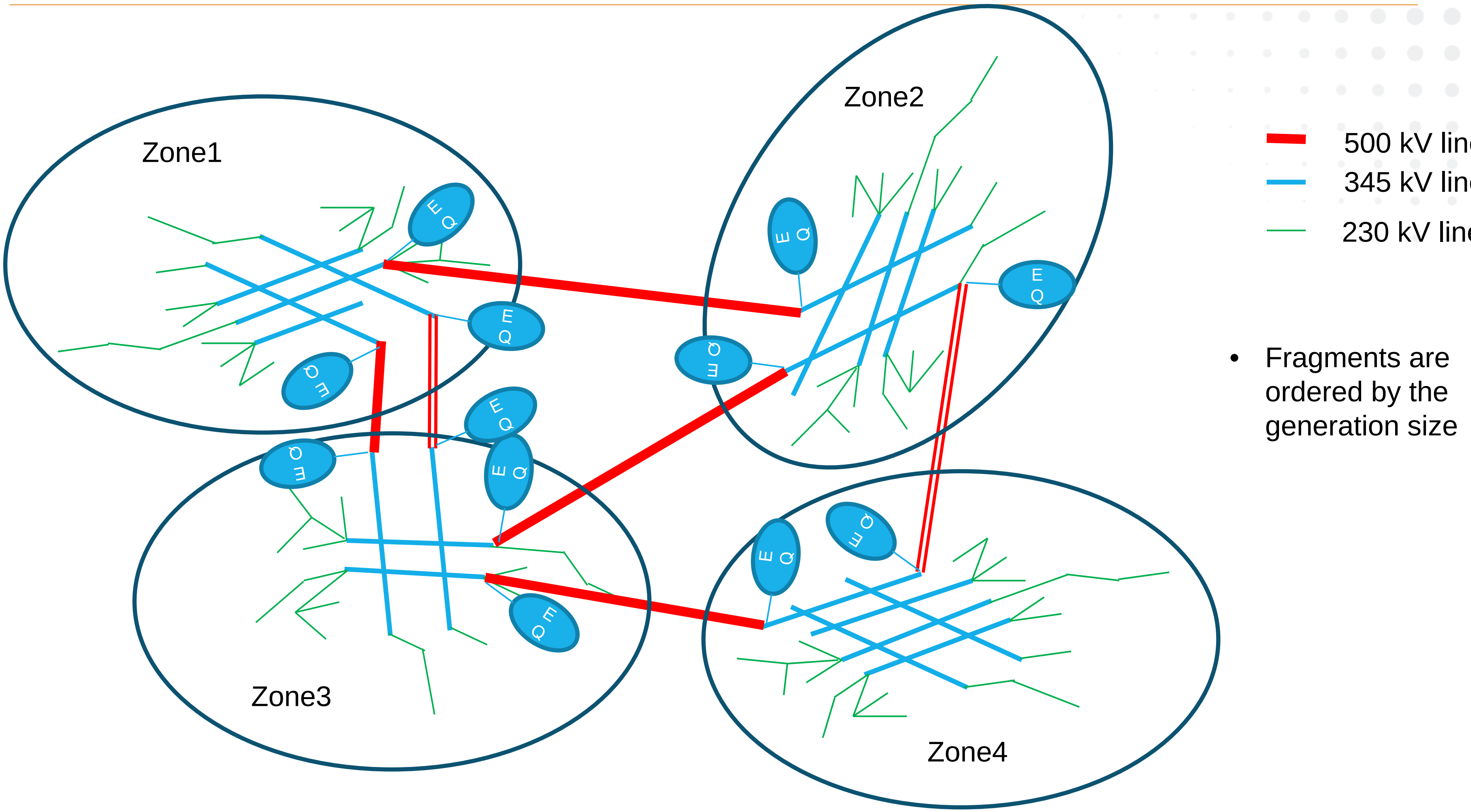
- **Development of Data Creation Tools**
  - Develop metrics for topology, parameter, composition, consistency of real-world datasets
  - Topology generation: graph theory based algorithms
  - Parameter population: deterministic and probabilistic approaches
  - Data anonymization
- **Generation and validation of open-access datasets**
  - Base cases of small-scale and large-scale models
  - Time-series scenarios
  - Three-level validation: component, system and application

A Fragmentation Approach

- "Deterministic" approach on the system fragment level for the most of system parameters
  - Real-world systems will be used
  - Each system model will be fragmented into zones, preserving:
    - Generation, load level
    - Lines, transformers, controllers
  - Data anonymization approach will be used
  - The zones will be recombined to form the desired system model
  - Creating tie-lines between zones through a graph theory algorithms

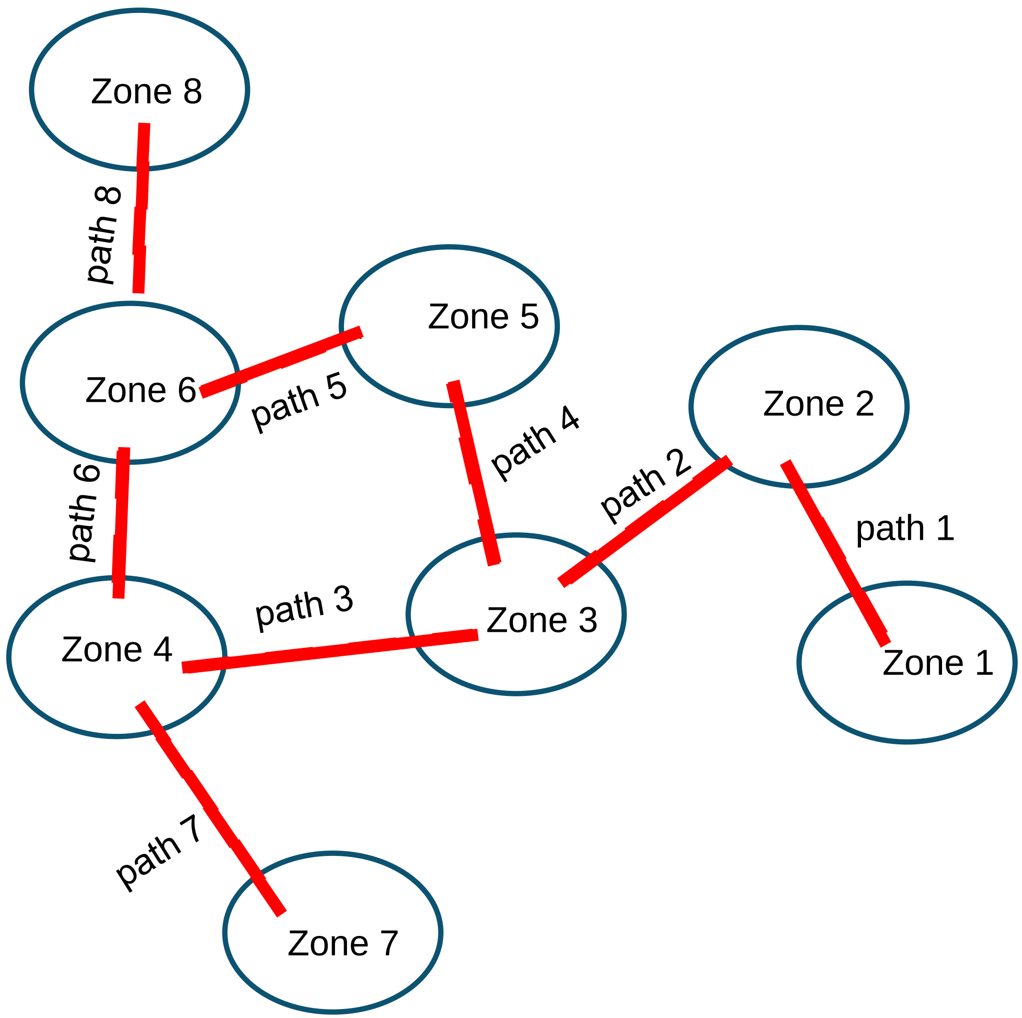


Prepare fragments from real-world models



- Fragments are ordered by the generation size

An iterative process to build the "kernel"



Inputs
- Desired size of the model
- A number of fragments with connectors

Outputs:
- Synthetic skeleton/topology (picture in the middle)
- Minimizing voltage difference between zones
- Minimizing line crossings
- Satisfying graph metrics
- Paths are ordered such that smallest zones are connected first.

Creating Key Grid Information

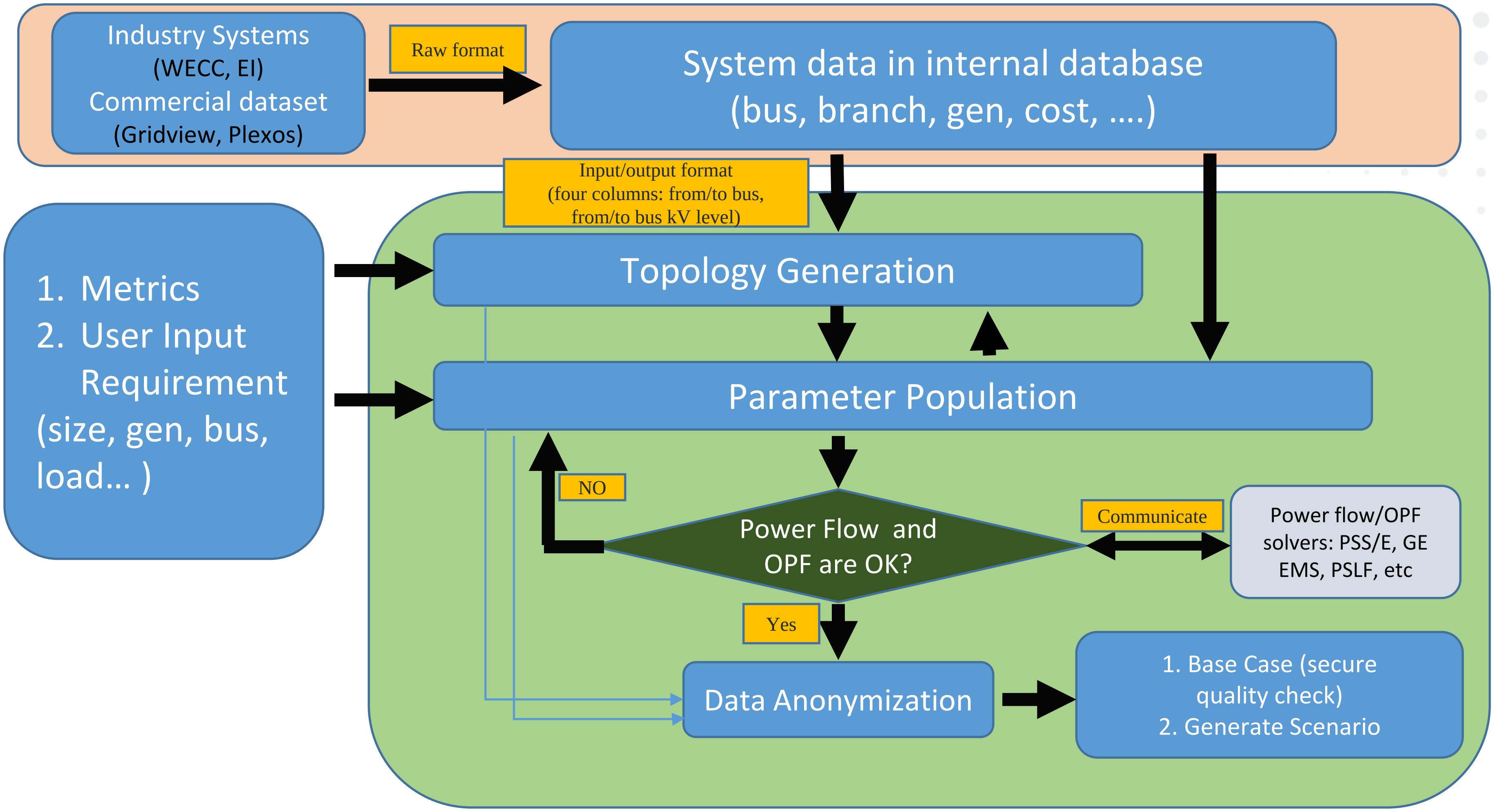
- A “probabilistic” approach for
  - Production cost/market bid data
  - Variable resources
  - Random factors added to the system load
- Distribution System Model Creation for VVO
  - Real-world feeder models and data will be collected
  - Applying a data anonymization approach

CHANGING WHAT'S POSSIBLE

Metrics for measuring realism

- **Graph-theoretic metrics**
  - Degree distribution
    - The degree of a node is the number of connections it has to other nodes
    - Degree distribution is the probability distribution of these degrees over the whole network
  - Average shortest path length
    - A path between two vertices (or nodes) such that the sum of the weights (number of edges in a path) of its constituent edges is minimized
    - Average number of branches between 2 buses
  - Diameter
    - The longest shortest path between any pair of vertices
    - The max number of branches between 2 buses (is a function of system size)
  - Average clustering coefficient
    - Ratio of actual edges between its neighbors to all possible edges
    - Clustering coefficient tells how well the graph nodes are connected with each other
- **Power grid parameter metrics**
  - Based on real-world characteristics, we will use the following typical statistical measures: 1) Mean value; 2) Standard deviation (STD); 3) Min value, and 4) Max value

SDET Tool Architecture

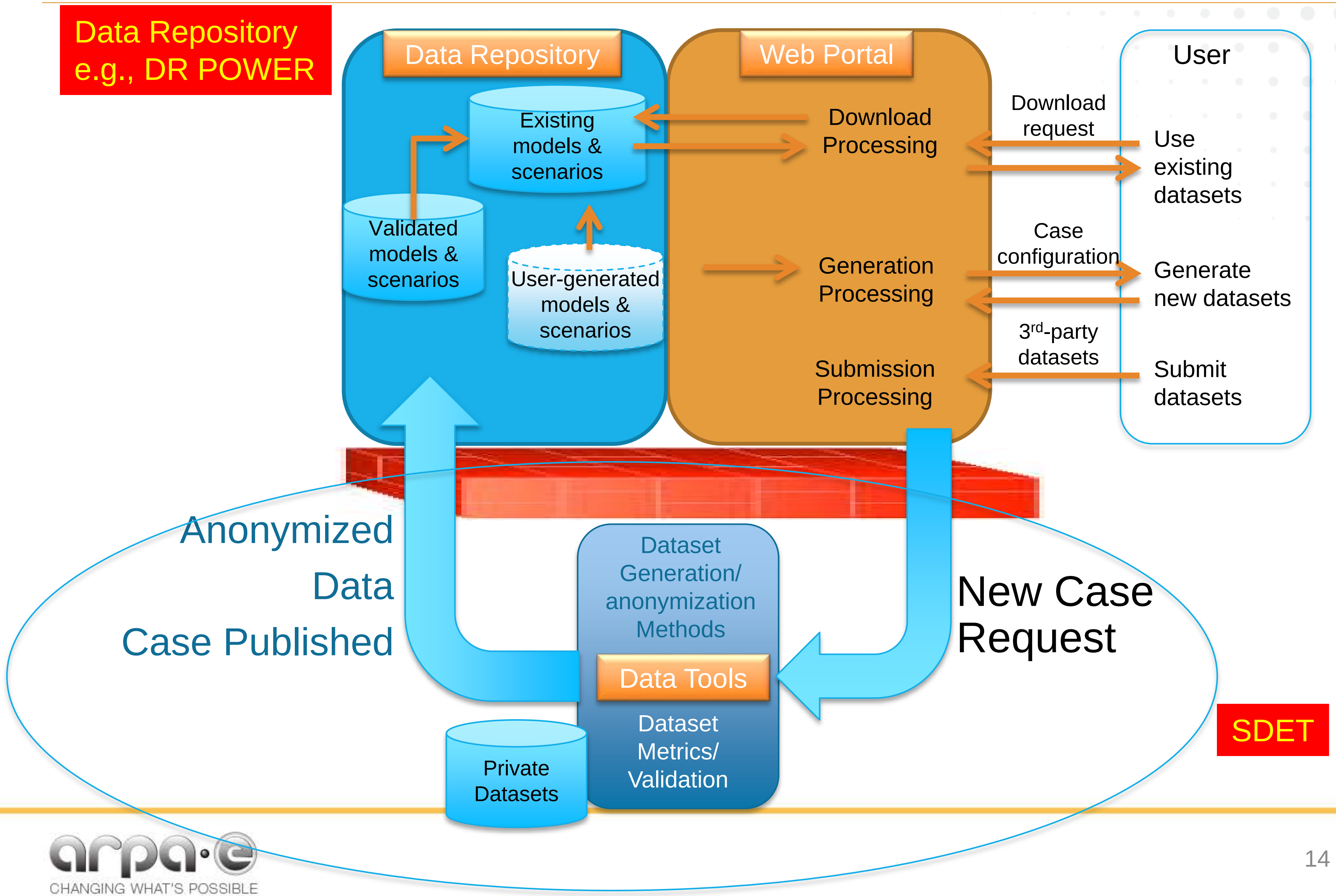


CHANGING WHAT'S POSSIBLE

Key Steps

1. Fragment Creation
2. Topology Generation
3. Fragment Reconnection
4. Base case AC power flow
5. System reinforcement following N-1 contingencies
6. Add generator cost curves
7. Base case AC OPF
8. Scenario generation

Use Cases and Relationship to Data Repository



FERC definition of CEII from 18 CFR 388.113

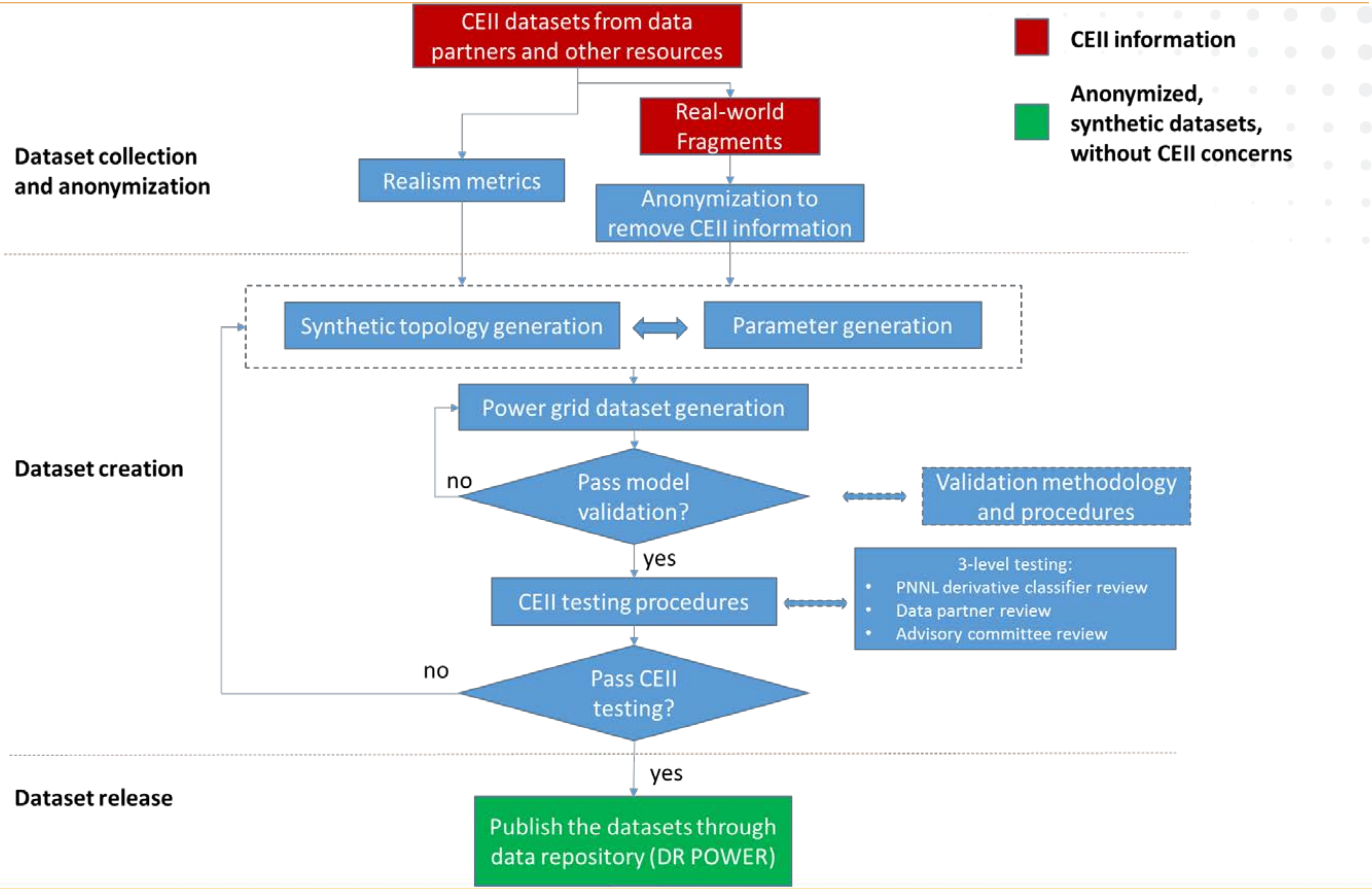
(2)*Critical energy infrastructure information means specific engineering, vulnerability, or detailed design information about proposed or existing critical infrastructure that:*

- ***(i)*** *Relates details about the production, generation, transportation, transmission, or distribution of energy;*
- ***(ii)*** *Could be useful to a person in planning an attack on critical infrastructure;*
- ***(iii)*** *Is exempt from mandatory disclosure under the Freedom of Information Act, 5 U.S.C. 552; and*
- ***(iv)*** *Does not simply give the general location of the critical infrastructure.*

(3)*Critical electric infrastructure means a system or asset of the bulk-power system, whether physical or virtual, the incapacity or destruction of which would negatively affect national security, economic security, public health or safety, or any combination of such matters.*

The more abstract the representation is, the less likely it would be classified as CEII, since it doesn’t map directly to any real physical equipment or locations.

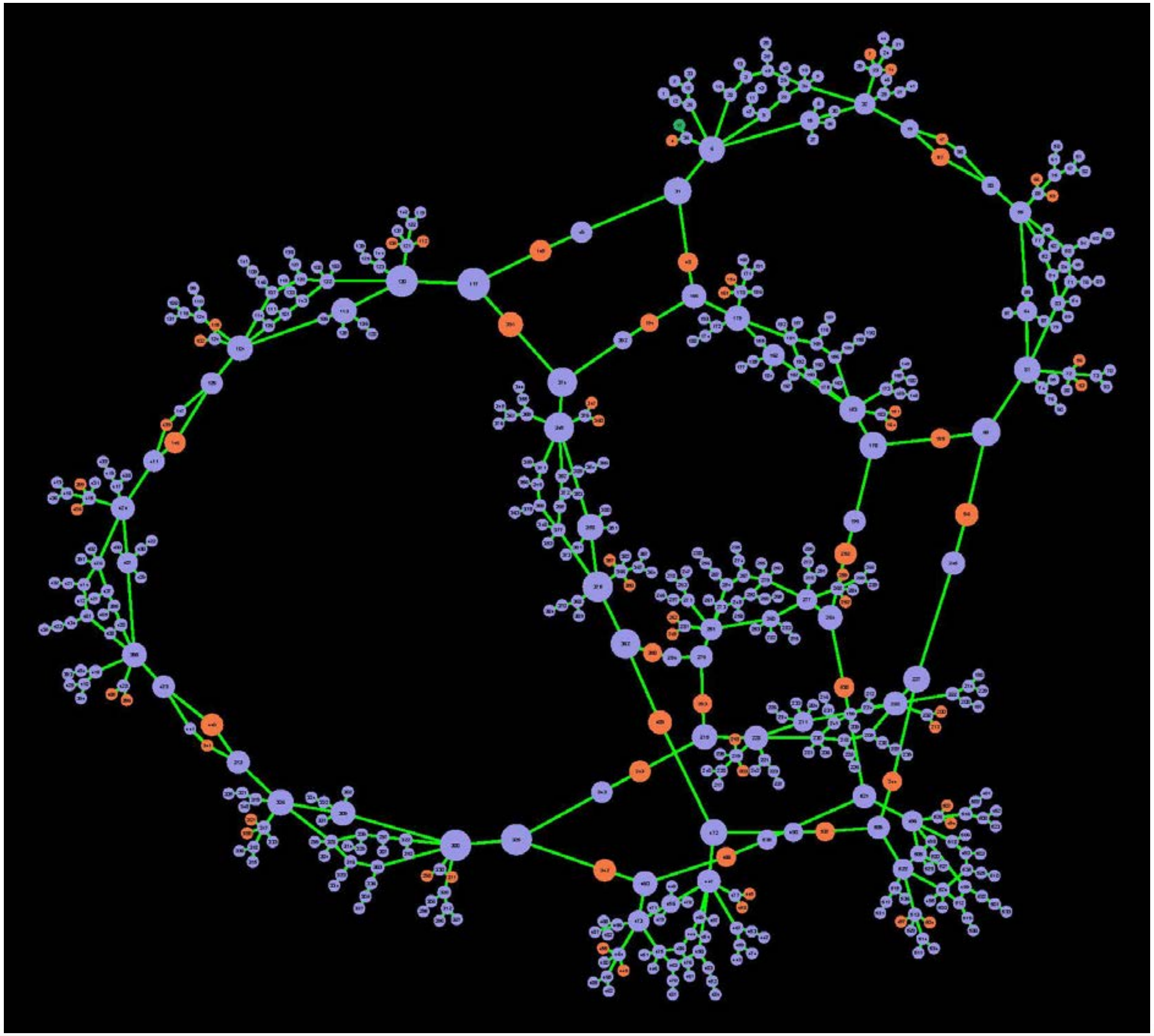
Curation Process



Achievements So Far

- Key modules ready
  - SDET framework in C++
  - PTI file parser, v33
  - Fragment creation code in python
  - Topology creation code
  - Fragment reconnection
  - Validation module through PSSE
  - Creation of the generator cost curves
- A few power system models with ~500 buses
  - Good convergence
  - Meeting metrics requirements
- A few power system models with ~3000 buses
  - Good convergence
  - Meeting metrics requirements

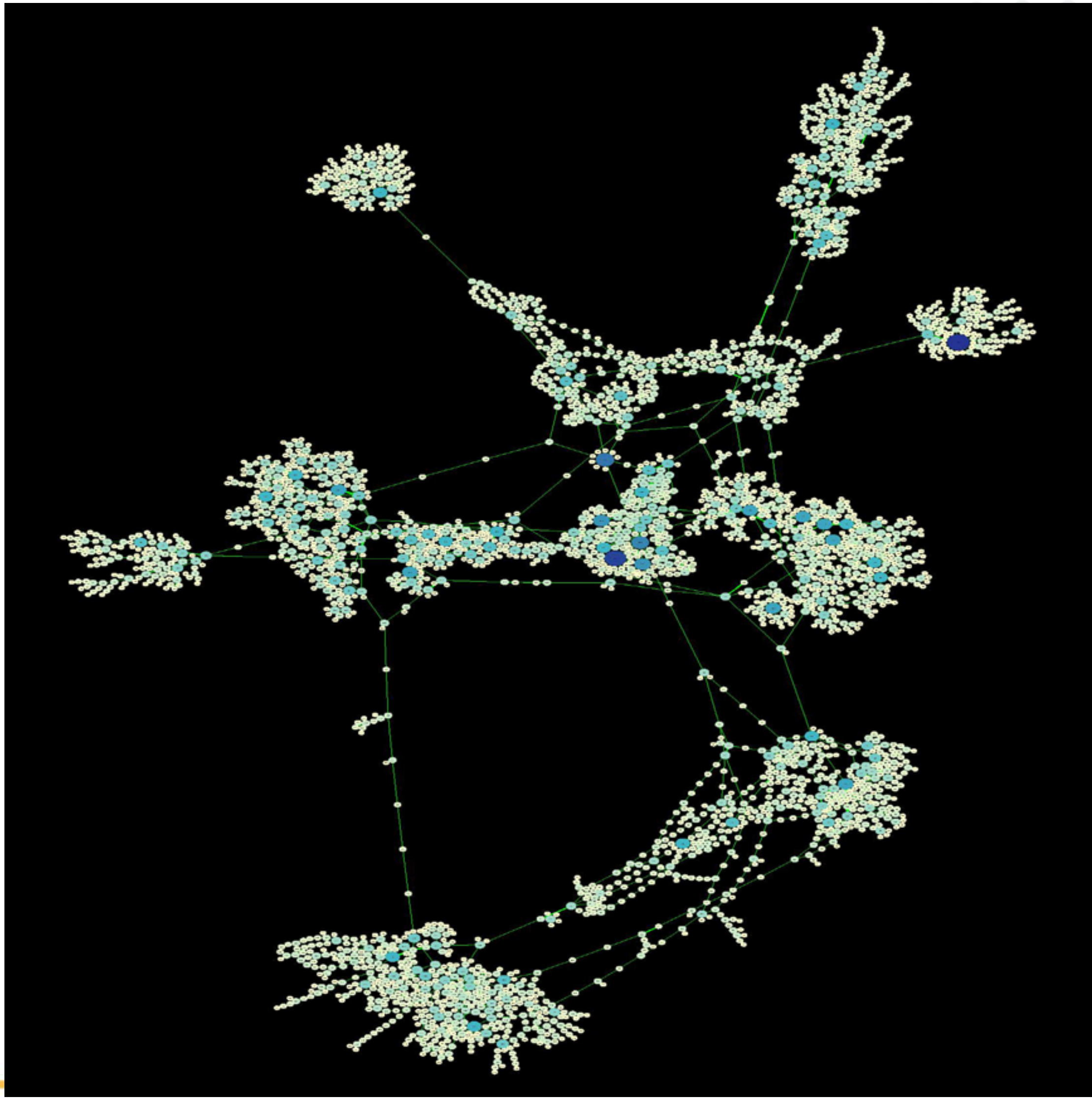
500 bus model generated



- 10 real-world fragments
- 45 tie lines created
- 528 buses
- 66 generators
- 6.3 GW of load

3000 bus model generated

- 21 real-world fragments
- 116 tie lines created
- ~3000 buses
- ~500 generators
- 36.5 GW of load



CHANGING WHAT'S POSSIBLE

Technology to Market and Outreach

- T2M Strategy
  - Expected products: datasets and data tools
  - Transition facilities: EIOC and PIC
  - Training and workshops
  - Tool adoption: offer datasets and tools to GRID DATA data repository
  - Community engagement: e.g. IEEE PES, PSERC, CURENT, FERC, Power Globe, power industry, etc.
- Intellectual Property
  - New software tools to be generated, protected by BSD-style open-source licenses
  - Potential patents

Conclusions

- Making datasets evolving is important to keep up with grid development and enable technology advancement
- Delivering datasets is important, but delivering data creation tools can enable data ***evolution***
  - Topology generation tool
  - Parameter population tool
  - Data anonymization tool
- Datasets and data creation tools are to be shared through GRID DATA repositories and professional communities

Questions?