



Visualization of Electric Power System Information

Workshop Proceedings

Benjamin Kroposki and Connie Komomua
National Renewable Energy Laboratory

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

Technical Report
NREL/TP-6A00-57280
January 2013

Contract No. DE-AC36-08GO28308

Visualization of Electric Power System Information

Workshop Proceedings

Benjamin Kroposki and Connie Komomua
National Renewable Energy Laboratory

Prepared under Task No. 2940.5017

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

NOTICE

This report was prepared as an account of work sponsored by an agency of the United States government. Neither the United States government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States government or any agency thereof.

Available electronically at <http://www.osti.gov/bridge>

Available for a processing fee to U.S. Department of Energy and its contractors, in paper, from:

U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831-0062
phone: 865.576.8401
fax: 865.576.5728
email: <mailto:reports@adonis.osti.gov>

Available for sale to the public, in paper, from:

U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
phone: 800.553.6847
fax: 703.605.6900
email: orders@ntis.fedworld.gov
online ordering: <http://www.ntis.gov/help/ordermethods.aspx>

Cover Photos: (left to right) PIX 16416, PIX 17423, PIX 16560, PIX 17613, PIX 17436, PIX 17721



Printed on paper containing at least 50% wastepaper, including 10% post consumer waste.

Acknowledgments

This report summarizes a workshop jointly sponsored by the National Renewable Energy Laboratory and the Pacific Northwest National Laboratory. The authors would like to thank everyone involved in making this workshop a success. And a special thanks goes out to the participants who freely shared their technical expertise and are respected for their enthusiasm, commitment, and key contributions.

Table of Contents

1	Introduction	6
1.1	Workshop Motivation and Objective	6
1.2	Workshop Structure and Guiding Questions.....	6
2	Workshop Summary	6
2.1	Participants.....	6
2.2	Agenda	7
2.3	Presentation Discussions.....	8
2.4	Roundtable Discussions	10
2.4.1	Around the room: Give us one idea – the most important need that is lacking today.	10
2.4.2	Around the room: Who are the audiences for visualization?.....	11
2.4.3	Around the room: Explain why you prioritized it the way you did.	11
2.4.4	Around the room: Is there any low-hanging fruit? What can we produce quickly while looking at the problems?.....	12
2.5	Summary and Conclusions.....	12

1 Introduction

In late 2012, the Energy Systems Integration Facility (ESIF) is opening at the U.S. Department of Energy’s (DOE) National Renewable Energy Laboratory (NREL). The facility includes 19 laboratories with a wide range of capabilities, and will give NREL and partnering organizations the opportunity to research electricity integration projects before deploying them in the field. The ESIF also includes visualization labs to help researchers understand the data collected during project experiments.

1.1 Workshop Motivation and Objective

To address what information should be made available in the visualization labs at the ESIF, NREL and the Pacific Northwest National Laboratory (PNNL) jointly held a workshop entitled “Visualization of Electric Power System Information” on September 11, 2012 on NREL’s campus in Golden, Colorado.

The objective of this workshop was to discuss what information should go in the visualization labs in the ESIF to allow a better understanding of high penetration renewables and energy systems integration opportunities.

1.2 Workshop Structure and Guiding Questions

The structure of the workshop included presentations followed by open forum discussion, designed to encourage interaction among the group of participants. Workshop discussions were guided by the following framing questions:

1. Why is there a need for research and enhancement to visualization needs for power systems?
 - a. Where are the current visualization systems lacking?
 - b. What issues can come about from lack of visualization?
 - c. What are the needs of an evolving power system?
2. What are the important issues and why?
 - a. What are the priorities?
 - b. Is there any low-hanging fruit?
 - c. Explore the justification of priorities.

The findings from the workshop are documented in this summary report.

2 Workshop Summary

The *Visualization of Electric Power System Information* workshop was held on the NREL campus in Golden, Colorado on September 11, 2012.

2.1 Participants

Name	Affiliation
Alvin Razon	DOE Solar
Annie Rhoad	Xcel
Anthony Lopez	NREL
Ben Kroposki	NREL
Carolyn Elam	NREL
Connie Komomua	NREL
Dan Getman	NREL
Debbie Brodt-Giles	NREL
Dennis Stiles,	PNNL

Erik Ela	NREL
Hongming Zhang	WECC
Hyungseon Oh	University of Buffalo
Jason Bank	NREL
Jodi Obradovich	PNNL
Josh Hambrick	NREL
Kenny Gruchalla	NREL
Mark O'Malley	University of Dublin College
Mohit Singh	NREL
Russ Philbrick	Polaris
Scott Crowder	NREL
Terry Penney	NREL
Trieu Mai	NREL
Yih-Huei Wan	NREL
Zea Flores	WECC

2.2 Agenda

8:30 Introduction and Roundtable

8:45 Energy Systems Integration Facility
Ben Kroposki

9:15 New Visualization Enhancements on the Xcel Trading Floor
Annie Rhoads, Xcel

9:40 PNNL Experiences – Visualization and Decision Support for the Power System
Dennis Stiles, PNNL

10:05 New Needs for Visualization: Bulk Power Transmission System
Erik Ela, NREL

10:25 New Needs for Visualization: Distribution System
Josh Hambrick, NREL

11:00 Roundtable Discussion – Why is there a need for research and enhancement to visualization needs for power systems.

1:30 Roundtable Discussion – What are the important issues and why.

3:15 Develop next steps on prioritized issues:

- Technical approaches
- Roles (lab, utility, vendors, etc.)
- Current opportunities
- Partnership opportunities
- Funding opportunities

3:45 – 5:00 ESIF Tour

2.3 Presentation Discussions

The following is a summary of discussions that occurred during the workshop presentations.

Presentation	Energy Systems Integration Facility	Ben Kroposki
Notes	Great advantage to manufacturers before going to market with products – lowers market risk	
Q&A	Are we able to bring in data from other sites off campus? Yes.	
Presentation	New visualization enhancements on the Xcel trading floor – Wind Visualization at Xcel	Annie Rhoads, Xcel, Lead Power System Trader
Notes	Day ahead planning, managing real time assets, purchase power contracts NCAR graphical runs every 15 minutes, and is then transferred into the graphical model <ul style="list-style-type: none">• Needs vary by operating company• Wind overspeed issues – we need a way to predict these situations• Wind ramp events – we need the ability to show the operator the event is happening• Managing wind around transmission constraints• Curtailments for economics during times of negative LMP• Understanding complexities of MISO charge types NCAR → PI → EMS Meteorologists on the floor, any sort of meteorological information (i.e. Google) look at NOA forecast and include NNCAR forecast – tying it into PI – security issues – not a lot of data coming out of NCAR system – could be integrated more seamlessly. Demand response only used at peak hours. Using the same process in all three markets.	
Presentation	PNNL Experiences – Visualization and Decision Support for the Power System	Dennis Stiles, PNNL
Notes	Rich area of research Key Challenges Slides <ul style="list-style-type: none">• How to translate data into information, then information into action to improve overall efficiency of the system from generation to end use.• Ability to work side-by-side with the EIOC and ESIF• Streaming data from 10K AMI installations in PNNL region• Amount of data 50 terabytes each year• Graphical contingency analysis tool• Probabilistic approach for ramping and transmission capacity adequacy tool – installed and evaluated at CAISO	

This is possibly an important area of research – fully tackle the science behind it – using concerted efforts to bring in more disciplines from across the laboratory.

Cognitive systems engineering – interdisciplinary approach

- Visualization – one key element supporting analysis and decision making
- BPA
- NASPI
- Creating visualization based on research findings that are tailored to real time operators specific work demands, leveraging the powerful perception-action skills of human, while taking advantage of powerful interface technologies

Important and rich field of research taught us a lot of important lesson – key lessons that to advance state of the art significantly – bigger problem than any one lab and DOE programming. Excited about being here – important data sets useful to NREL and others. Find a way to get closer on a lot of this kind of research.

Use it with the data as well to figure out how humans will interact with unexpected events – need to design it into the model from the beginning.

Q&A Why do we need these tools?

For money, reliability, and the ability to tackle problems in the future. Operators are going to have to get better; tools are going to have to get better.

Q&A How do you navigate human subjects?

IRBs – for each research project. Institutional review board – for human subjects = need to get permission make sure human subjects protected from an ethical point of view. Make sure the participants are protected.

Presentation **WISP – Western Interconnection Synchrophasor Program**

Zea Flores WECC

New visualization tools

- ALSom/Psymetrix – general visualization
- Montana Tech/ U of Wyoming/PNNL
- V&R Energy

Wide area View (WAV) – in-house development tool

Map – paths, lines, frequencies PMU status, phase angle differences, ACE; alarms; daping gages, updated every 50 seconds

Visualization: **need a better way to understand smart alarming**

Biggest struggle: Congestion management

Additional: High level view to monitor problems

- Calling out the most important problems
- Ability to get more detailed information quickly
- Ability to have all the data needed on minimal amount of screens
- Data presented so that it's not overpowering

- Q&A Is it necessary to distract out renewables, or is it included in the whole picture?
We are focusing on whole-picture reliability; however renewables are making more of an impact on reliability.

2.4 Roundtable Discussions

The following is a summary of the roundtable questions and discussions.

2.4.1 Around the room: Give us one idea – the most important need that is lacking today.

The discussion leader recorded the answer from each participant, listed them all on a board, and then asked the participants to rate the importance, or priority, of each answer on a scale of 0 to 4, with 4 being the highest priority.

1. Integration of electricity markets and power system operations - 4
 - a. Prices outside the borders
 - b. Market operators to see phase angles, power flow
 - c. Two-way interaction with data displayed
2. Very high penetration of renewables - 2
 - a. Simulated control room to try out different visualization techniques and see what the data needs in this
 - i. Forecasting
 - ii. Load demand response options
 - iii. How to display to make operations more efficient
3. Simple visual tools to present to policymakers - 3
 - a. To help them make decisions on big things
4. Renewables introduce uncertainty. A way to control the uncertainty and include renewables rather than pushing it out. How do you present renewables to the operator as a tool to use rather than a constraint or problem? Mitigate uncertainty. - 1
5. Careful distinguishing types of visualization tools.
 - a. Analysis tool, more interactive interfaces for operators rather than static data.
6. Interactive, customizable tools that evolve based on interactions - 2
7. Forecast actual wind power data power displays. How to display probabilistic info? - 3
8. Most efficient way to get the data out of the database.
 - a. Different options to view the same data.
 - b. How to display the data in a meaningful way?
 - c. Efficient way to show the meaning of the data. - 3
9. Standardization – data, data sharing between entities - 1
10. Anticipation of demand response, display of current response - 4
11. Combining simulation data with measurement data. Display the discrepancies between the two for validation purposes. - 2
12. Data rates based on what the application is. What type of data do you need and how does it compare to other applications. -1
 - a. Load modeling
 - b. PMU – how does it related to a weather forecast that’s only 15 minutes
13. Visualization (at least in the near term) focused more on distribution planning rather than operations.-3

14. Future visualization capabilities -0
15. Tools during emergency / critical times - 1
16. Integration and correlation of data to present state of system-0
17. Intelligence on data-2
18. Presentation of diagnosis, rather than list of symptoms-4
19. Understand the roles of distribution operator of the future to understand need of tools and presentation-3
20. Share lessons learned and best practices – industry build out to share data -2
21. Educational-based videos around the operations of the grid. Of the general public.-1

2.4.2 Around the room: Who are the audiences for visualization?

- a. General public – 1 vote
- b. Policy makers – 4 votes
- c. System operators – 1 vote
- d. Researchers – 1 vote
- e. Analysts – 3 votes
- f. Planners – 8 votes

2.4.3 Around the room: Explain why you prioritized it the way you did.

1. Tools during emergency / critical times
 - a. Washington is talking about this
2. Focus on displaying meaningful presentations
 - a. Management that pays for the tool and want the cool. Don't design for the cool, design for understanding.
3. Tools for the state of the art, more capabilities to look ahead
4. Showing a lot of data in a meaningful way
5. Validation of the measurements we have vs. simulations – helps us to understand future systems ahead of time – trying to create models that simulate that
6. Simple tools to present to policy makers and decision makers
7. Reducing a large amount of data to a meaningful visualization
8. Present on diagnostics rather than simulation
9. Providing common data formats or plumbing – all tools required access to data – not a big driver for creating data formats to allow customers to move to competitors.
10. Customizable tools based on the user; often, people want to see the same data in different ways or to different audiences
11. Combining simulation data with measurement data – distinguish between simulation and reality
12. Most efficient way to display massive amounts of data
13. Customizable tools
14. Better understand roles of operator and future needs
15. Community between industry and research to discuss results and ideas
16. Displaying probabilistic info in a manageable way

2.4.4 Around the room: Is there any low-hanging fruit? What can we produce quickly while looking at the problems?

- Educate the general public.
The discussion mainly revolved around misconceptions of the public. Different levels of complexity based on audience. The misconceptions that smartgrid.gov is sending to the people. Tell the truth or it will come back to haunt you.
- Have data preprocessing computing the value that is making that data valuable.
Support a wider range of users – an evolving toolbox for different users.
- The power industry in the U.S. is conservative; they don't want to invest in these things before they really need it. Reactive rather than proactive.
The ESIF can provide more confidence to implement into their everyday operation.
- Vendors – we test software, send it back, and have back-and-forth that operators can actually use and like. It would be helpful if researchers can do this more before we get it.
- Make a training environment available.
Have operators work through the procedures.
- Hold operator symposiums.
Bring all the operators together at the ESIF to discuss the “what if's”?

2.5 Summary and Conclusions

After the exercise was complete and the comments were heard by all, the participants and discussion leaders agreed that the most important need lacking today is:

- **Displaying the data in a meaningful way**
 - Need an efficient way to get the data out of the database
 - Need different options to view the same data
 - Need an efficient way to show the meaning of the data.

The most important audience: **Planners**

The discussion went in two different directions today:

1. Capabilities to educate the public
2. Capabilities for new technologies and innovative solutions for operators.

Top considerations include capabilities for new technologies, renewable and demand response, and questioning how we can use the research at this lab and translate that into presentations and visualizations that can be used by interested parties.

Q&A: WECC participant: Are you looking at some short term projects?

No. More of this is long term capabilities. Really we just wanted to get a general vision of what this can be used for.

We will get together internally at NREL on next steps and send out to the group. This group will be kept in the loop to provide feedback.