Proceedings of International Joint Conference on Neural Networks, San Jose, California, USA, July 31 – August 5, 2011

"Back-to-Basics": Operationalizing Data Mining and Visualization Techniques for Utilities

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Abstract— **Today, the family of Hawaiian Electric utilities, consisting of Hawaii Electric Light Company (HELCO) on the Big Island of Hawaii, Maui Electric Company (MECO) on the islands of Maui, Molokai and Lanai and Hawaiian Electric Company (HECO) on the island of Oahu, are contending with PV penetrations in excess of 20 percent during high electricity demand days (e.g. weekdays) and over 60 percent penetration during light load demand days (e.g. weekends) on certain distribution circuits. With the emergence of more, low-cost photovoltaic (PV) systems and consumer self-generation programs, such as net energy metering and feed-in-tariffs, today's utilities are facing a fundamental shift towards a need to get more visibility to customer-sited, distributed generating resources (DG). The Hawaiian utilities are among an emerging set of utilities around the world leading the nation in contending with high levels of renewable penetration on their distribution systems. Hawaiian Electric Utilities are pursuing efforts to *gather, evaluate and target* (*GET*) relevant resource datasets in conjunction with time synchronized system data to enable planning, forecasting and operations with high penetration of variable, distributed renewable resources.**

I. INTRODUCTION

While distribution circuits are typically capable of withstanding load changes over a range of conditions, the lack of visibility, accurate modeling and information for control of increasing levels of variable, distributed generating resources (DG), such as photovoltaic systems (PV), on the distribution circuits have created increasing reliability and power quality concerns. Utilities are essentially "blind" to these behind-the-meter resources and need new data and analysis capability and tools to help capture and understand distribution level impacts, particularly when it comes to demand side resources providing generation onto the grid. At these penetration levels, there is also growing concern that the traditional "rules of thumb" for design of protection and distribution systems are beginning to reach their limits or are being compromised. In order to address these concerns, Hawaiian Electric Companies have initiated a number of high resolution data monitoring and evaluation efforts on the islands.

This paper presents some of the issues/challenges facing the Hawaiian utilities, our preliminary findings and the "back-to-basics" approach to addressing needs. Current efforts are pushing traditional utility analytical tools and require new data mining and evaluation capabilities to support real-time operations and planning. Efforts help develop "insight" for training the workforce, engaging expertise to help develop tools and managing variable DG resources while accounting for their locational benefits and impacts. Field deployment experiences and preliminary results for some of the pioneering projects will be discussed to show progress toward integration. Future work and benefits will also be summarized.

II. STRATEGY & APPROACH

As part of a "back-to-basics" strategy, the family of Hawaiian Electric Companies are partnering with industry experts, commercial product vendors, academia, national laboratories, and other utilities dealing with significant variable DG resources to collaboratively work on ways to better manage growing levels of resource locations and data on the electric systems. Our approach includes:

- Gathering of high fidelity field data from on resource and time correlated grid conditions from various locations around the islands
- Evaluating datasets (existing and new) using appropriate data analysis tools/techniques and develop techniques as needed, and
- Targeting "low-hanging" integration opportunities to deploy monitoring devices, assess data, pilot technologies and visualization tools, and integrate new modeling and forecasting capabilities.
- Investigating advance machine learning algorithms for use in processing high resolution datasets

A. *Data Monitoring Field Devices*

As part of the first step toward increasing visibility to DG resources, the Hawaiian Electric Companies began deploying a variety of high resolution solar irradiance and solar availability monitoring devices throughout the

Manuscript submitted February 21, 2011.

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operating territory. These devices were deployed at a number of utility substations and at select customer sites. Figure 1 shows two such devices. Figure 1a) is a standard solar irradiance monitor mounted on a protective housing. This TJD-1 device provides a reference measurement of the solar intensity in W/m^2 for the local area served by the substation. Figure 1b shows the solar availability locational monitors (LM-1) installed at the substations. The LM-1 device is essentially a small photovoltaic panel whose output is calibrated to a reference solar irradiance monitor (TJD-1) in the area. The LM-1 is also used to provide a visual indication of cloud coverage and to estimate an equivalent aggregated installed PV output potential (or solar availability) for the region serviced by the substation.

(a)

(b)

Fig. 1. Field deployed solar monitoring equipment a) solar irradiance monitors TJD-1 substation setup and b) LM-1 solar availability monitors.

A number of power quality monitors were also deployed at select commercial and customer locations to track the PV output performance and provide validation data for modeling purposes.

B. Data Analysis Needs

To manage and assess new data being collected, additional data servers, storage devices and data communication equipment are needed. Preliminary deployments of new field sensors at distribution substations are bring back gigabytes (GB) of high resolution (2-second) data using the substation communication infrastructure (i.e., SCADA, microwave, cellular network) on a daily basis surpassing existing historian and data management capabilities. As part of the field monitoring, over two dozen new time stamped data parameters from the distribution substation and circuits are also being transmitted back to operations and stored for further mining and analysis in support of distribution system modeling and validation efforts. Local weather and conditions are also being noted in addition to review and extraction of relevant data from other utility databases as illustrated in Figure 2.

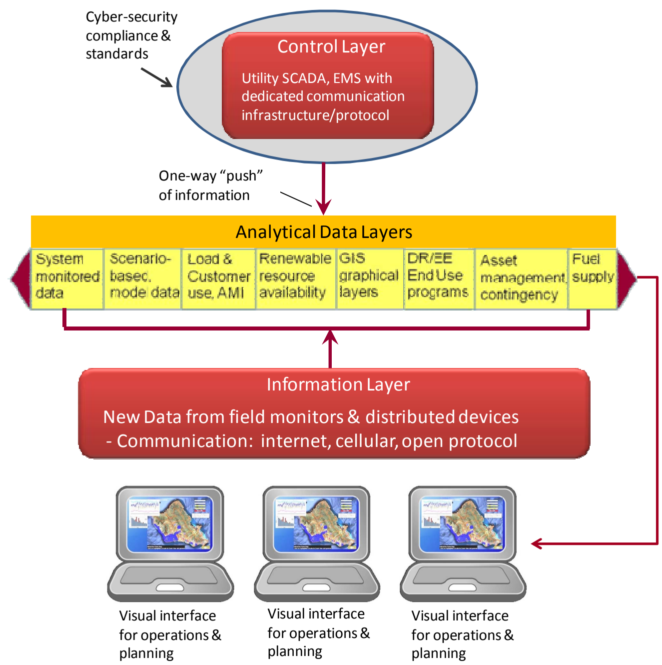
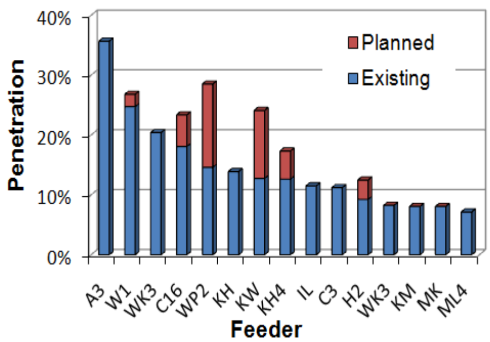
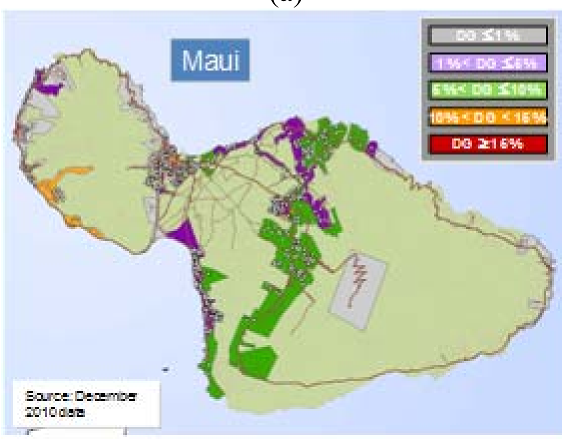


Fig. 2. Illustration of other relevant repository of information for review and analysis.

As such, new analysis tools and visualization techniques to extract data from multiple databases, process various formats need to be used to analyze the data. Data intensive analytical software, such as Matlab and an exploratory database called TREX by Referentia Systems, Inc., are being evaluated to manage the large volumes of data and conduct statistical analysis on the new field monitored data. State-of-the-art geographic information system tools (GIS) are also being created to link new renewable data to system conditions and provide a visual and geographic means to track and trend DG development around the islands. Figure 3 shows how circuit penetration statistics shown in a) is being depicted in the Locational Value Map (LVM), which provides developers and customers a regional representation of where high penetration circuit levels exist.



(a)



(b)

Fig. 3. Circuit penetration statistics (a) translated to geographically referenced Locational Value Maps (LVM) (b).

III. Preliminary Findings & Results

Efforts thus far are helping to provide visibility to where the DG, load and system constraints are. By better utilizing existing system data and targeting new field monitoring efforts, the potential exists to develop more responsive load control and management capability. For the island grids, ability to plan ahead and "forecast" needs will be critical in maintaining reliable operations and cost-effective energy services while pursuing clean energy alternatives. Initial data assessments and calibration efforts are highlighted below.

A. Data Analysis & Calibration

High resolution solar data from the TJD-1 and LM-1 are been collected for the islands. While calibration of the LM-1 to the reference solar irradiance monitors are still in progress and preliminary results show great promise. Figure 4 shows how well the LM-1, located at the substation, can be used to estimate output from a PV facility connected at the substation. Just as the larger PV panels at the facility, the smaller LM-1 exhibits the same ramping response due to passing clouds without complicated cosine corrections or sensor limitations. The LM-1 also accurately captures the morning cut-in and evening cut-out of the PV panel production.

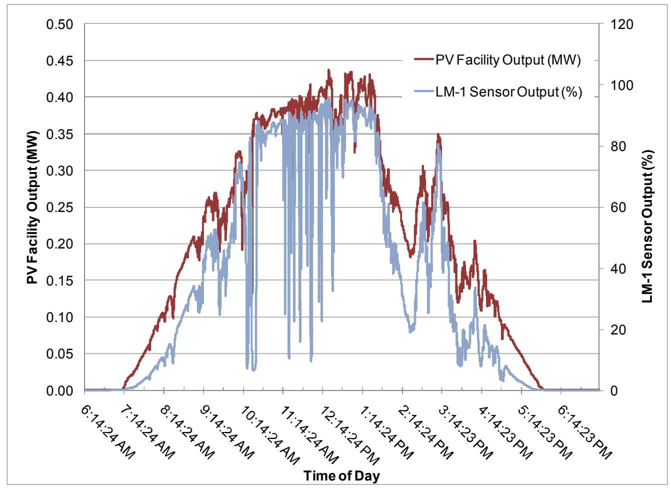


Fig. 4. LM-1 (uncalibrated) tracking PV facility output.

Data collected is being used to calibrate and validate the use of the LM-1 sensors for use in estimating installed PV capacity aggregated at the substation. Figure 5 shows LM-1 performance testing under different simulated cloud cover by percentage (25%, 50%, 75% panel coverage) and comparative cut-in, cut-out and ramp rate response to an irradiance monitor (Figure 5).

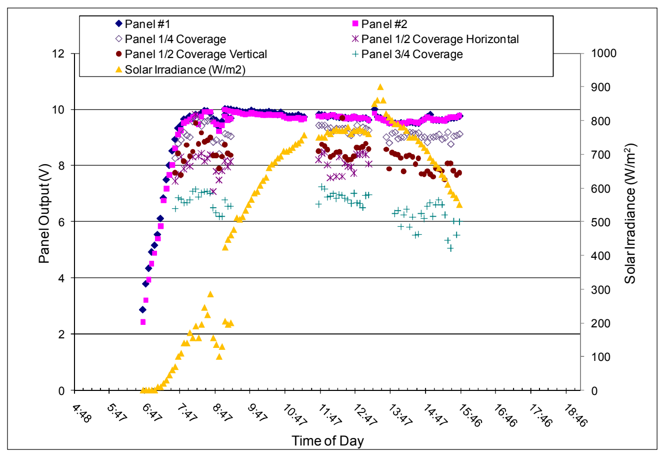


Fig. 5. LM-1 panel calibration to reference solar irradiance sensor and output performance with different degrees of simulated cloud cover.

Once validated, a simple Equivalent Aggregated Circuit-level (EAC) DG estimation methodology (Figure 6) can then be used to estimate DG production at a resolution down to the distribution substation level for resource forecasting and system operations.

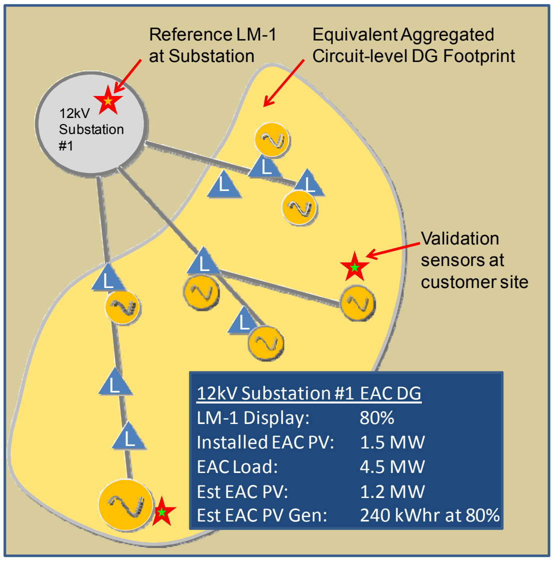
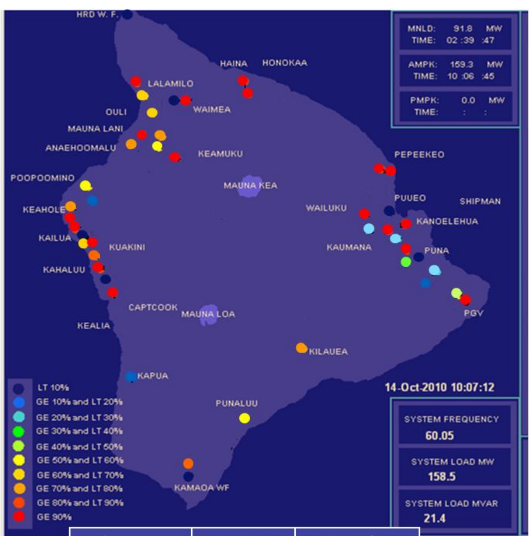


Fig. 6. Illustrative use of LM-1 sensor and validation sensors used to estimate an Equivalent Aggregated Circuit-level output from all DG (i.e. PV) installed on circuits at the substation node.

B. *Visualization Pilots*

Figure 7 shows the preliminary solar operational display currently being piloted at HELCO.



Region	Est. Gen MW	Connected MW
North Hawaii	1.3	1.7
East Hawaii	2.9	4.1
West Hawaii	2.6	3.7
South Hawaii	0.0	0.1
Total PV (MW)	6.8	9.6

Fig. 7. Solar availability display piloted at HELCO using LM-1 sensors deployed at substations.

System operations now have a visual read and quantified estimate of PV availability and geographic location on the system. By tracking and trending this data over time, operators can begin to develop a sense of the resource variability over different time periods, under various weather conditions and for different geographic regions. Information may also be used to inform development of more responsive load control algorithms and dynamic control strategies.

C. *Data Mining Potential*

In combination with visualization tools, there is a growing need to investigate and explore computational algorithms that can help distill the volumes of data (e.g. field data, modeling data) into actionable trends and inform decisions. While state estimation and probabilistic trending are currently utilized in utility automatic generation and control tools, they rely on "traditionally" collected system data from the utility network (e.g. SCADA, generation recorders, substation field device recorders or other historical archives). With the integration of renewables, the data streams become more complex and the needs expand beyond the utility's traditional data gathering network into arenas like weather forecasts, wind data, solar and cloud information at the local distribution level. The questions of what data, how much data and where to gather the data remain challenging issues.

As an example of efforts to address the questions of what data, how much data and from where, the Hawaiian Electric Companies are working with the western utilities and the wind energy forecasting community to pilot a remote sensing and computational modeling approach called WindSENSE for wind ramp rate forecasting. Wind ramps are essentially variability (ups and downs) in the wind resource that can cause wind facilities to increase or drop production in a very short amount of time. As noted in the February 26, 2008 event in Texas, these ramps can cause major power quality issues to potential blackouts. Funded in part by the U.S. Department of Energy, the effort in Hawaii couples advance numerical weather prediction models and meso-scale models and remote sensors, called SODARs (Figure 8), to gain insight on placement of an optimal wind monitoring network (WindNET) for wind and ramp rate forecasting.

(a) (b)

Fig. 8. a) Stationary and b) mobile Atmospheric Research & Technology (ART) sodar systems deployed as part of WindNET.

Using an observational targeting methodology developed by AWS TruePower that mined computational results, a set of indicators including temperature, pressure, gradients and wind shear was first identified (Figure 9) and then used to optimally site field monitoring. As shown in Figure 10, the computational results guided the siting of remote sensors to locations deemed most useful in monitoring to provide a "heads-up" on potential wind ramp events. While field verification and validation efforts are currently in progress in Hawaii, preliminary results show significant improvement in the WindNET to forecast wind ramp events within a short time period (1-2 hrs).

While coupling computations with experiments is not a new technique for the research community, the confidence to rely on these tools to inform grid operations and planning is and is part of operationalizing tools into the field. Coupling advance computational techniques to focus field deployment and verification campaigns such as the WindNET has helped improve forecasting capabilities and can provide for a sustainable deployment of optimally located sensors versus a trial-by-error approach.

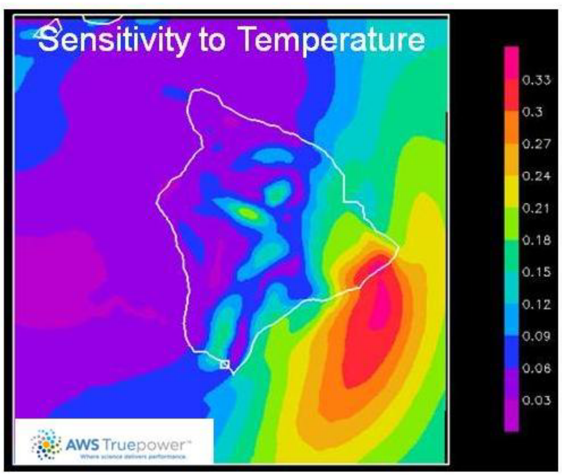


Fig. 9. Numerical simulation showing sensitivity to temperature and locations to monitor for changes.

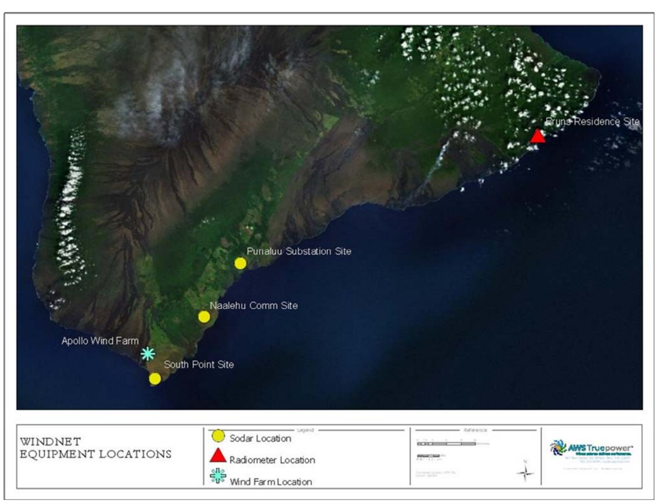


Fig. 10. WindNET monitoring locations identified based on observational targeting technique (developed by AWS Truepower).

D. *Continuing Efforts*

A number of *GET* data efforts are underway across the Hawaiian Electric utilities. These efforts assist the utilities gain understanding of the resources, develop expertise with tools and reliably integrate variable renewable resources. Through the various collaborations, findings and lessons learned will hopefully aid other mainland utilities, industry vendors, developers and modelers to continue building field monitoring experience and data management, validation and new techniques for real-time operations.

IV. Summary

As penetration levels continue to increase with aggressive national and state RPS targets, challenging integration questions are being posed by utilities around the world. Today, the Hawaiian utilities are contending with over 20%-60% penetration of variable generating resources on distribution circuits. Thus the development of new real-time visualization tools for operations using high fidelity field data and improved modeling techniques are envisioned to help Hawaiian utilities proactively plan, reliably integrate and cost effectively manage additional levels. While it will take time and resources to gather sufficient data for the "back-to-basics" approach, this process will help to build a more informed and knowledgeable workforce with the "seat-of-the-pants" confidence in using appropriate forecasting, data analysis/mining techniques and integration resources currently being developed.

Acknowledgment

The Renewable Integration Team from the Hawaiian Electric Companies would like to thank the U.S. Department of Energy, the California Public Utility Commission and the Sacramento Municipal Utility District for their sponsorship of efforts. The team also acknowledges our partnership with various industry vendors to help push the envelope. We also value the interactions with students and faculty at the University of Hawaii on the data monitoring and analysis initiatives. These utility-vendor-academia partnerships and nationally supported efforts will help inform reliable adoption of distributed resources/technologies and ensure progress toward more affordable and sustainable clean energy options for the nation. The work presented represent the culminating efforts of a number of key personnel from across the Hawaiian Electric Companies (HELCO/MECO/HECO) who are endeavoring to make the system more reliable and cost-effective for our customers. Without their dedication and ingenuity, these pioneering efforts would not be possible.

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