Geographic Decision Support Systems To Optimize The Placement Of Distributed Energy Resources

Emergent Research Forum papers

Vivian Sultan
Claremont Graduate university
Vivian.Sultan@cgu.edu

Hind Bitar
Claremont Graduate university
Hind.Bitar@cgu.edu

Abstract

The United States electric utility industry is moving toward a new power grid that will accommodate bi-directional energy flow and the incorporation of Distributed Energy Resources (DERs). Currently, utility companies lack tools to identify locations on the electric grid that can sustain DERs' adoption. This research explores the use of Geographic Information Systems (GIS), a class of tools for developing spatial models, with the aim of optimizing the placement of DERs. The intent of this research paper is to propose a Geographic Decision Support Systems (GDSS) model as a solution for the utility industry to assist in the DERs' portfolio choices and provide actionable information for utilities, system operators, and power producers. Claremont city has been chosen as the research site to demonstrate the applicability of the proposed model. This will also serve as the basis for future research.

Keywords

GDSS, new power grid, smart grid, DERs

Introduction

America's paradigm of one-way electric power generation and distribution is no longer sustainable (Department of Energy, 2015a; Department of Energy, 2015d, p.54). The electric distribution system cannot meet the demand for cleaner power and more customer control of energy bills. Additionally, the existing one-way power grid cannot accommodate the growth in the penetration of Distributed Energy Resources (DERs) such as solar rooftops (Gergen, Campopiano & Meyer, 2014). In 2014, the California Public Utilities Commission (CPUC), which is the state regulatory body responsible for electric utilities, asked for DERs integration into the electric distribution system. Later, in 2015, the CPUC issued a Distribution Resources Plan (DRP) ruling to change the current electric distribution system into a new system that accepts two-way energy flow between customers and their respective utility companies. The two-way grid allows customer involvement and their choice of new technologies for power generation, transmission, and consumption (California Public Utility Commission, 2015a; Gergen et al, 2014).

Despite the availability of new technologies for solar, wind, and hydro energy generation, along with other great improvements in the electric utility industry, the electric transmission and distribution systems have remained largely unchanged (Department of Energy, 2015b). The key question is how utility companies can match supply and demand across the power grid, especially since the electric grid's bi-directional traffic congestion is growing rapidly. According to United States Department of Energy assessments, a superior system for matching supply and demand is necessary (Department of Energy, 2015d).

As stated in the "Analytic Research Foundations for the Next-Generation Electric Grid" 2015 report, there are many important characteristics that the next-generation electric grid system has to implement to improve the current grid system. Some of the features are combining generation and storage, involving customers, allowing DERs' adoption, and improving power quality. The report's producers developed a mathematical model that could be implemented in an effort to design, monitor, analyze, and control the next-generation electric grid system. The authors argued that this mathematical model could be used in a Decision Support tool to determine the emerging problems and instantaneously calculate corrective actions, which are extremely difficult tasks based on today's current system capabilities. The proposed model in the report aimed at ensuring optimal operation and robustness of the grid. Physics and engineering theories were the backbone of this model.

In the aforementioned report, GIS was only used as a display tool that showed the transmission grid, electricity interconnections, electric load, and the geomagnetically induced currents (GICs). We argue that, in addition to visualization, GIS is an extremely powerful tool that can be used for decision support, planning, and predictive modeling especially as utility companies are in the process of integrating DERs into the grid. Being able to build a custom GDSS solution that incorporate the mathematical model in the above report will enable these capabilities to meet utilities' specific geo-processing needs.

The U.S. Department of Energy Office of Science is calling for researchers to assist the utility industry in its transition to a 21st century grid. In response to the call, our paper addresses this research question: "How can GIS be employed to optimize the placement of DERs?" In this research paper, we develop a GDSS model for the utility industry to aid in DERs portfolio choices and provide actionable information for utilities, system operators, and power producers. The intended audiences for this research are utility corporations, state-level decision-makers, and other stakeholders who are concerned about the future of the United States electric power system.

Background and Foundation

The United States' power grid is incapable of integrating DERs due to the lack of energy storage means and its inefficiency for transporting excess energy (Department of Energy, 2015a; Department of Energy, 2015d, p.54). The current electric power paradigm cannot deal with the fluctuation in energy supply and demand appropriately. Americans pay high electricity bills as utility companies procure energy from expensive sources in order to meet peak demand for excessive-energy-consuming communities (United States Department of Energy, 2015b; Investopedia, 2015).

The utility industry aims to transform the network topology to a smart grid that accommodates various DERs types. The smart grid can be defined as a new class of technology, which uses computer-based remote automation to bring the electricity delivery system into the 21st century (The Department of Energy, 2015). Advanced electrical network technology permits the two-way energy flow between suppliers and consumers. Improvement of power quality, customer participation in distributed energy generation, optimization of energy resources, and electricity cost reduction are among the key benefits of this new grid (Department of Energy, 2015f). The new grid must be robust, flexible, and responsive to the integration of DERs and must accommodate additional customers' low energy generation resources. The Electric Power Research Institute estimates that \$338–\$476 billion will be invested in DERs, intelligent grid technologies, advanced electrical network systems, and applications for the utilities' new grid in the next twenty years (Department of Energy, 2015d, p.55). Tools for optimizing grid operations and those that can predict future problems are vital within the modern grid design. Forecasting tools to balance the supply and demand of electric power are essential for the utility industry to resolve the potential bi-directional grid traffic congestion.

According to the U.S. Department of Energy Quadrennial Technology Review (2015e), energy-related research is essential to help create a resilient, economically efficient, secure, and environmentally responsible energy system. The research community must seize this opportunity and collaborate with energy officials if a revolution in the United States electric power system is underway (Department of Energy, 2015e). In the next section, GIS, its applications in utilities, and its use for predictive modeling in other industry sectors are examined. The intent of that section is to prove the suitability of GIS to optimize the placement of DERs. Then, we develop a GDSS model. Claremont city has been chosen as the research site to demonstrate the applicability of the proposed GDSS model.

Literature Review

GIS Application in Utilities

The finding from the National Electric Transmission Congestion research project is the primary resource highlighting the congestion problem. This study provides an overview of the congestion issue across the United States and the use of GIS to provide analysis. However, the findings were inconclusive regarding resolutions or recommendations (U.S. Department of Energy, 2015c). Many GIS-based maps and resources are available, for example, the Renewable Auction Mechanism (RAM) Program Map, Southern California Edison (SCE) Distributed Energy Resource Interconnection Map (DERiM), and San Diego Gas and Electric's Interconnection Information Map. SCE relies on Cooper Power Systems' modeling software to execute the integrated capacity analysis and utilizes GIS maps, DERiM, to present their congestion study results. The reason for which SCE developed DERiM in July of 2015 was to primarily connect the company with DERs' developers and presents the results of their capacity analyses (Southern California Edison, 2015).

GIS for Predictive Modeling

Predictive modeling is a process for determining a mathematical correlation between two or more variables (Dickey, 2012). Future dependent variables can be estimated and derived if their relationships to independent variables are understood. Predictive modeling has become a useful aspect of GIS due to its application in public health (Idowu, A., Okoronkwo, N., & Adagunodo, R., 2009) and public work asset management (Totman, 2013). GIS has been employed to improve public works predictive modeling procedures in the area of maintenance and asset management. GIS can be used in practically any field, and is only limited by the availability of geospatial data.

Model Design

This study proposes a GDSS solution to assist in DERs portfolio choices and provide actionable information for utilities, system operators, and power producers. The goal is to optimize the placement of DERs considering the electric circuit capacity constraints, the households' solar rooftops potential electricity output, and the projection of households' profiles adopting DERs.

Input data is the households' demographics, SCE parcel map that includes power electric lines and the potential solar energy with the capacity in kilowatts for a specific area in Los Angeles County, USA. Based on the input data, the following three sub-models are created as shown in Figure 1:

1. A predictive analysis model based on households' demographics data to yield a projection of households' profiles adopting DERs. Utilizing logistic regression, a model has been designed in Microsoft Azure machine learning with the following key variables:
   - Dependent variable: Customer's adoption of the solar rooftop, where the model output is either "yes" to the solar rooftop adoption or no (Y/N).
   - Independent variables: such as the solar system cost saving, solar system value, electricity usage, customer's demographics and expenditure data.
2. A model to calculate households' solar rooftops electricity output based on LA County solar rooftops' rankings. According to the Photovoltaic software (2016), the key elements to compute the energy resource are the total solar panel area, the solar panel yield, and the performance ratio, which is the coefficient for losses.
3. A model to combine electricity output from the current system with the solar rooftops' potential electricity yield. The output map from sub-model 2 is spatially joined with DERiM map (DERiM Web Map, 2016) in order to do the integrated capacity analysis by circuit line.

The outputs are property location and boundaries (geospatial data), proximity to power lines, and potential residential sites suitable for DERs' adoption. The required data is mainly retrieved from the Los Angeles County GIS Data Portal and the SCE's DRiEM.

The proposed predictive model can be applied for all Energy Informatics use cases such as commercial, residential, and factories. In this paper, we chose to focus on the "residential" parcel type in LA County due to the data availability. We further chose to use Claremont City as a demonstration to provide an evidence for our research findings. Claremont city is located in the eastern border of Los Angeles County in California. According to 2014 United States Census, the population is 36.054. The main reason for choosing this city is the data availability. Electricity service is provided by SCE in the city of Claremont. Hence, data is available and accessible from SCE DERiM and LA County solar map.

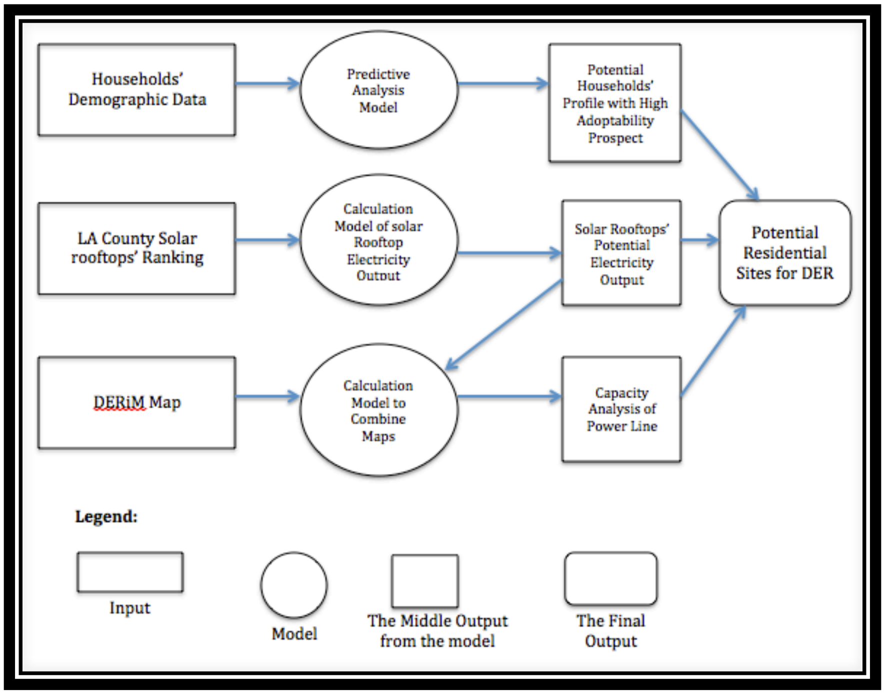

Figure 1: Geographic Decision Support System Model To Optimize DERs' Placement

Concluding Remarks

This study aims at addressing "How can GIS be employed to optimize the placement of DERs?" To answer the research question, we have defined GIS, investigated its applications in utilities, and examined how it can be employed for predictive modeling. A GDSS model is developed utilizing ArcMap 10.3 software to assist utility companies in prioritizing locations, which need infrastructure work, and detecting regions where DERs may provide net benefits.

From this research, we argue that not only can GIS be used as a display tool, but it also offers a solution to analyze the electric grid distribution system. Our model provides evidence that GIS can perform the grid's integrated capacity analysis in replacement of the software currently employed by utilities.

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