Electric Substation Emergency Disaster Response Planning Through the Use of Geographic Information Systems

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***Abstract*— There are many reasons behind power failure that we are facing today. When examining some of these reasons, the research team found that an electric substation failure could cause massive power outages. In this research-in-progress paper, we investigate the important relationship between electric substations and the important infrastructure they support. Specifically, we try to answer the research question: "Which important facilities would be affected by the power outage from an electric substation level?" To answer the question, we build a proof of concept Decision Support Tool using Geographic Information Systems to inform emergency responders which important facilities need to be attend to first. We select nursing homes and emergency facilities in Southern California, USA as the facilities of interest for the proof of concept.**

Keywords- Emergency Disaster Response; GIS; Power outage.

I. INTRODUCTION

Electrical power, within a short time, has become a necessity of modern life. Our work, healthcare, leisure, economy, and livelihood depend on the constant supply of electrical power. Even a temporary power outage can lead to relative chaos, financial setbacks, and possible loss of life. Our cities dangle on electricity and without the constant supply from the power grid, pandemonium would break loose. Power outages can be especially tragic when it comes to life-support systems in places like hospitals and nursing homes or systems in synchronization facilities such as airports, train stations, and traffic control. Though our lives are interwoven with electricity, outages happen more often that we perceive. An estimated economic cost of power interruptions to U.S. electricity consumers is $79 billion annually in damages and lost economic activity in a 2006 report [1]. A preliminary update of the report put the number approximately at $110 billions in 2014 [2].

As a result, power failure should be treated with the urgency it deserves. In general, there are three causes of power outages: (1) technical failure in the hardware components, (2) environmental-related issues, such as winds, tornadoes, animals, and (3) human-induced errors, e.g., acts of terrorism. The devastating effects of power outage have prompted county-level, state-level, and federal-level investigations [3]–[6]. While maintaining the overall grid reliability is an important issue and being pursued by other researchers, this article investigates a specific issue in power outage, especially in the sudden outage at the substation level.

Power failure at the distributing site such as at a substation is an event that could cause massive power outage. For instance, a 2017 power outage in San Francisco shut down power to businesses, an important rail station, a federal court, and 90,000 inhabitants [7]. The electrical substation is the part of a power system in which the voltage is transformed from high to low or low to high for transmission, distribution, transformation and switching [8]. Substations are normally owned and operated by an electrical utility and are generally unattended, relying on Supervisory Control and Data Acquisition (SCADA) for remote supervision and control. Power transformers, circuit breakers, bus bars, insulators, lighting arrestors are the main components of an electrical substation [8]. Any mechanical failure of these components could lead to a power outage.

In this research-in-progress paper, we investigate the important relationship between electric substations and the crucial infrastructure they support. Specifically, we try to answer this research question: "Which important facilities would be affected by the power outage from an electric substation level?" To answer the question, we built a proof of concept Decision Support Tool using Geographic Information Systems (GIS) to inform emergency responders which facilities need to be attend to first. We select nursing homes and emergency facilities in Southern California, USA as the facilities of interest for the proof of concept.

In Section II, we examine utilities emergency response planning and GIS applications in various sectors to establish GIS as an appropriate solution in the research endeavor. In Section III, we detail steps in which we design a GIS model design to build the proof of concept and present it. In Section IV, we discuss our findings.

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II. BACKGROUND LITERATURE REVIEW

In this section, we discuss about the need for a GIS application in dealing with the emergency response planning in the electric utility domain. First, we describe the current emergency response planning landscape in the domain, then we briefly introduce GIS and demonstrate the utility of GIS in different sectors. With the proven usefulness in planning and responding to disasters, the electric utility domain could also be benefited from the GIS technology.

A. Electric Utilities Emergency Response Planning

Electricity is a crucial product many of us take for granted. We scarcely think about it, unless we don't have it. Because electricity plays such an important role in our lives, we rely on electric companies to provide a reliable supply of on-demand power. Companies constantly plan for emergency situations that could impact their ability to generate or deliver power. Overall, the industry has a strong track record of maintaining high levels of reliability [9].

No matter how well the industry is prepared, incidents of power outage still happen. As a result, every electric company has a contingency plan for dealing with power outages. In this plan, there is a detailed instruction for restoring electricity. Typically, one of the first steps a company takes – to respond to significant outages – is to identify where the impacted areas are and who are in danger. Restoration then proceeds based on established priorities. If business operations or households are disrupted, customers expect to know how long they will be impacted. Then, estimated restoration time will be established, monitored, adjusted, and communicated to impacted customers. Regulators and local government officials will also be notified regarding the outage and the impact. All in all, electric utilities strive to meet customer needs through effective risk assessment, mitigation, preparedness, response and communications.

Despite the fact that the electric utilities are doing their parts in restoring service, communities also partake in the emergency response to ensure safety for the community members. However, the practice of emergency response planning varies considerably among communities. In some, the planning process is quite formal: there is a specific assignment of responsibility to an office having an identifiable budget. In other, it is informal: responsibility is poorly defined and a limited budget is dispersed among many agencies [10]. Therefore, there is a need to understand the impact of power outage in the community and which important facilities are immediate affected, especially in the communities where informal emergency response is the norm. With a more holistic view of an emergency event and its related geographical areas, facilities, and population, emergency responders can act more effectively.

B. Geographic Information Systems

The Environmental Systems Research Institute defines GIS as a class of tools for seizing, storing, analyzing, and demonstrating data in relation to its position on the Earth's surface [11]. Analysts utilize GIS to view different objects' locations and study their relationships. Satellite as well as tabular data can be entered into GIS for a single map display. GIS applications include recognizing site locations, mapping topographies and also developing analytical models to forecast events [11].

The utility companies have started to employ GIS but primarily as a display tool and not so much as an analytical tool [12]. There are several applications that exist demonstrating the usefulness of GIS, especially in California: Pacific Gas and Electric Company's Solar Photovoltaic and Renewable Auction Mechanism Program Map, Southern California Edison's Distributed Energy Resource Interconnection Map, and San Diego Gas & Electric's Interconnection Information Map [13]. With the advent of spatial analysis and the importance of geographic nature of emergency response, GIS has started to gain more popularity, thanks to the utility of the tools in solving pressing problems in this field.

C. GIS Applications In Various Sectors

GIS assists with public works departments' budgets and maintenance work prioritization [14]. Michael Isun, an engineer technician for Public Works Road Operations Division, stated that "We use GIS throughout our entire operation, from data collection and asset management to maintaining our predictive models and developing our annual budgets" [14].

In addition to the application of GIS in public works, it has been employed as a forecasting tool to stop and control the spread of infections and diseases in public health. Idowu et al. [15] discussed an instance where GIS was employed to predict the malaria epidemic hot-spots in Nigeria. In this scenario, GIS succeeded to stop the malaria epidemic in a country where malaria incidents were excessive with 8-12.5% mortality rate [15].

Considering GIS success in solving significant problems for public work and public health, we chose GIS to create our Decision Support proof of concept. Not only can GIS be used as a display tool, but it also can be used in analytics and modeling. The proof of concept in Section III will highlight how GIS could aid emergency responders in a case of substation power failure.

III. PROOF OF CONCEPT DESIGN

In this section, we delineate our steps in collecting data and designing a prototype for the GIS application. First, we describe the data that we used and how we got them. Second, we state the software that we utilized to create the proof of concept. Lastly, we display the design steps we took to create the prototype.

A. Data Collection

For the design of the proof of concept, we limit our data collection to the spatial extent of an area that encompasses five cities reside in the San Gabriel Valley area of Los Angeles County, Southern California: Claremont, La Verne, Glendora, San Dimas, and Pomona. We obtain the nursing home data from the Homeland Infrastructure Foundation. There are three types of nursing homes: continued care, retirement community, and assisted living. Given our spatial extent, we chose to include all three types. In addition, we extracted the Urgent Care Facilities from the same dataset. We excluded hospitals in our dataset, only focusing on medical clinics. In addition, we relied upon the US Census Tract Parcel data to provide us with the commercial and residential areas of the spatial extend. While there is an interest of expanding study into the residential demographics, it is outside the scope of our study.

For the substation data, we utilized the Southern California Edison (SCE)'s Distributed Energy Resources interconnection Map (DERiM) Capacity Analysis Data. Since Southern California is serviced by one public company, SCE, this map is adequate to understand the overall electricity makeup of the region. The SCE's DERiM includes a majority of the electricity components: power electric lines, the capacity analysis in kilowatts by circuit line, and the substation locations. The data was utilized to situate and develop an area that is proximal with electric power distribution centers and substations to measure which specific areas would be affected by a potential power outage or outage caused by a natural disaster.

B. Design Software

The project utilized ArcGIS mapping platform for windows desktop. ArcGIS is used for creating and using maps, compiling and editing geographic data, analyzing mapped information, sharing and discovering geographic information using maps and geographic information in a range of applications, and managing geographic information in a database. We used the ArcGIS 10.3 developed by Environmental Systems Research Institute (ESRI) for designing the proof of concept.

C. Design Steps

First, we create a map with the spatial extent that encompasses five cities reside in the San Gabriel Valley area of Los Angeles County, Southern California. We then locate all nursing homes, urgent care facilities, power substations, and power lines in the vicinity, the perform spatial joins to create linkages between them. We then proceeded to color-coding to separate each power substations and its connected facilities. Figure 1 is the final result.

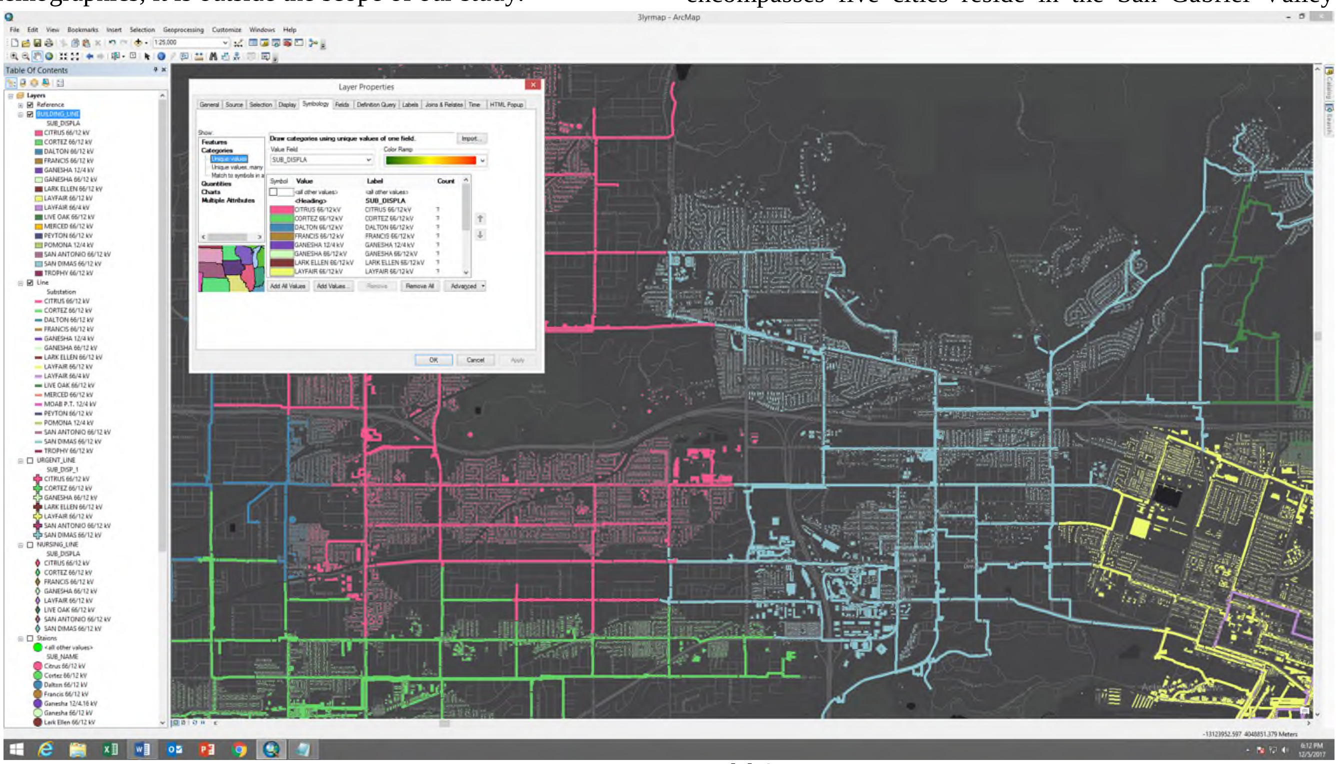

Figure 1. Design Model Output

IV. Discussion and Conclusion

In this research, we build a proof of concept to create linkages between power stations, power lines, nursing homes, and urgent care facilities. The outputs of this study show each substation and its connected lines with nursing homes and urgent care facilities through different color-coding. This could become a tool in which inter-city governments can use to coordinate to response in an emergency to power failure at the substation level. In other words, the prototype provides locations of important facilities that are affected by the power outage. The coordination effort could be diverted to assist the most pressing facilities, as demonstrated by the use of nursing homes and urgent cares in the prototype.

In future iterations of the prototype, we envision a full-scale emergency response platform for different types of critical facilities targeting the most vulnerable populations, such as children hospitals and hospice. The platform can also assist different non-critical facilities but important, e.g., schools, administrative governmental buildings, and churches. In addition, this emergency response could provide utility companies with the understanding in regards to prioritization of a power backup based on the specific needs of each community.

REFERENCES

[1] K. H. LaCommare and J. H. Eto, “Cost of Power Interruptions to Electricity Consumers in the United States,” *Energy Int. J.*, 2006, 1845-1855.

[2] J. Eto, “The National Cost of Power Interruptions to Electricity Consumers - An Early Peek at LBNL’s 2016 Updated Estimate,” in *IEE PES*, Boston, MA, 2016.

[3] J. M. Lee Morgan, “Blackout sparks multiple investigations,” *sandiegouniontribune.com*, Sep-2011. [Online]. Available: http://www.sandiegouniontribune.com/news/watchdog/sdut-power-surges-back-on-2011sep09-story.html. [Accessed: 26-Mar-2018].

[4] Governor Cuomo Press Office, “Governor Cuomo, Displeased with Length of Power Outage, Directs Investigation into Rochester Gas & Electric’s Preparation For and Response to Windstorm,” *Governor Andrew M. Cuomo*, 11-Mar-2017. [Online]. Available: https://www.governor.ny.gov/news/governor-cuomo-displeased-length-power-outage-directs-investigation-rochester-gas-electrics. [Accessed: 26-Mar-2018].

[5] A. Morris, “Senator Ricardo Lara Calls for Independent Investigation of Long Beach Power Outages,” *Long Beach Post*, 25-Jul-2015.

[6] Y. Steinbuch, “FBI joins probe into power outage at Atlanta airport,” *New York Post*, 19-Dec-2017.

[7] N. Chandler, “Substation Failure Causes Massive Power Outage in San Francisco,” *Transmission & Distribution World*, 26-Apr-2017. [Online]. Available: http://www.tdworld.com/substations/substation-failure-causes-massive-power-outage-san-francisco. [Accessed: 26-Mar-2018].

[8] US Department of Agriculture, “Design Guide for Rural Substations.” United Stated Department of Agriculture, Jun-2001.

[9] National Academies of Sciences, *Enhancing the Resilience of the Nation’s Electricity System*. 2017.

[10] US Department of Homeland Security, “National Response Framework.” US Department of Homeland Security, May-2013.

[11] ESRI, “Lesson 1: Why GIS?,” in *Understanding GIS--The Arc/Info method*, 6th ed., Redlands, CA: Environmental Systems Research Institute, 1992.

[12] V. Sultan, “Exploring geographic information systems to mitigate America’s electric grid traffic congestion problem,” in *Computational and Business Intelligence (ISCBI), 2016 4th International Symposium on*, 2016, pp. 74–79.

[13] California Public Utilities Commission, “Distribution Resources Plan (R.14-08-013),” *Distribution Resources Plan*, Jul-2015. [Online]. Available: http://www.cpuc.ca.gov/General.aspx?id=5071. [Accessed: 26-Mar-2018].

[14] D. Totman, “Model predictions: GIS helps public works manage assets,” *American City and County*, 17-Apr-2013. [Online]. Available: http://americancityandcounty.com/gis-amp-gps/model-predictions-gis-helps-public-works-manage-assets. [Accessed: 26-Mar-2018].

[15] A. P. Idowu, N. Okoronkwo, and R. E. Adagunodo, “Spatial predictive model for malaria in Nigeria,” *J. Health Inform. Dev. Ctries.*, vol. 3, no. 2, 2009, 30-36.

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