Illuminated Running Vest
(Technical Paper)

Energy Accessibility in Urban and Rural Communities
(STS Paper)

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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General Research Problem - Access to Reliable Electricity Sources

How has the increased need for electricity in American societies created a responsive desire for reliable access to electricity in developing communities?

The development of the electrical infrastructure in the United States began in the early 20th century (“History of Electricity,” n.d.). The electrical infrastructure in the United States was initially developed to revolve around cities, where most of the industrial revolution was taking place in the early 1900s. Over the following century, infrastructure was slowly built in order to bring electricity to rural areas. As electricity became available to most households in American communities, access to electricity became a necessary part of developing societies.

Modern American society revolves around the rapid development of technology. It is in a state of rapidly increasing demand for electricity, a variety of power sources, and an aging electrical infrastructure. The fragile American electric system has been failing to supply reliable power to its consumers and having a profound effect. In 2003, the Northeast Blackout affected over 50 million people and cost between $4.5 billion and $10.3 billion in economic losses (“Power Infrastructure,” 2016).

The increasing volatile electricity demand has created a need for alternative sources of electricity that are more reliable. Solutions that provide alternative options to the traditional electric grid have been presented in order to satisfy the need to reliable electricity access in developed communities. However, not all communities are presented with the same opportunities to have consistent electricity sources, resulting in different rates of community growth and development.

Alternative solutions encompass a wide range of technologies. These technologies have been developed in response to the diverse set of uses for electricity. For example, electricity is used to heat homes, provide light sources, power cell phones and gadgets, or make food. Each use provides opportunities for new technologies to be invented in order to satisfy the need for more reliable access to electricity.

Technical Research Problem - Illuminated Running Vest

How can we determine a mechanical means for recharging batteries when no electrical outlet is available?

While jogging, humans exert large amounts of energy through their motion that has the potential to be harnessed for various uses. In addition, over 100,000 pedestrians are injured every year, with an increased likelihood of crashes occurring at night due to reduced driver and pedestrian visibility. In an attempt to solve both of these issues, a team consisting of myself and five other fourth year mechanical engineering students will research, design, and construct a human powered LED running vest to be packaged and sold on the consumer market. This illuminated running vest will address not only safety concerns for users, but also satisfy an increased demand for constant access to electricity in order to function in modern society.

The design of the vest consists of two linear generators placed on the upper chest area of a reflective safety vest. These generators are attached to supercapacitors to store the energy produced, which, in turn, are connected to LED strips that are attached to the front and back of the vest. The linear generators function off of Faraday's law and the principle of magnetic induction. As a magnet passes back and forth within a conductive coil, a current is generated due to the motion of the induced electromagnetic field. While running, the magnets inside of the linear generators will move up and down with the user’s stride, bouncing off of springs at the top and bottom of the generators. The coils connect to superconductors that will store the energy and slowly dissipate it out the LEDs on the vest. LEDs were chosen as light sources due to their efficiency in electricity consumption, and small bulb size.

Currently, illuminated jogging vests sell from anywhere between \$15 to \$60 on market. The goal for our technical project is to completely produce the device for under \$50. Given the lack of other external monetary sinks like batteries or electricity to recharge, it is seen as acceptable for the vest to be priced higher than most on the market. In addition, as work continues on this vest, investigations into part availability and price will be done in the next semester to determine if the price can be further reduced. Most of the research and investigation done will be completely proprietary as we cannot find any other similar vests. The literature relating to linear generators typically revolves around large scale applications such as wave energy rather than such personal, small-scale use.

We will work within a 9-month timeframe, with major milestones occurring in December and May. In December, we will have completed a detailed drawing of our anticipated design, as well as ordered any necessary materials. Over the following four months, we will assemble our product and subject it to prototype testing, completing our final product in May. To do so, we have access to all of the machines in the laboratories such as 3D printers, soldering irons, and a broad range of adhesive devices. The ideal result is a functional, ergonomic, and marketable product that will be patented.

STS Research Problem - Energy Accessibility in Urban and Rural Communities

Energy Inequality in the United States - How has this discrepancy between the availability of electricity in urban areas versus rural areas impacted their respective communities?

Introduction

Access to electricity is consistently defined as a factor that facilitates the development and growth of communities. Without access to a reliable electric grid, communities suffer from less economic opportunities, poor healthcare, and fragile infrastructure ("Energy Inequality—Conceptual Notes and Declarations—IIASA," n.d.). Access to electricity differs between communities throughout the United States. Perhaps the most significant difference occurs between urban and rural communities. Regardless of geographic location, most households have at least basic access to electricity. However, electric grid reliability differs across the country due to increasing volatile demand and aging infrastructure. Therefore, the relationship between a community and its respective electrical infrastructure creates a unique sociotechnical system. In my research project, I will investigate the possible effects of the weak electrical infrastructure in the United States and its impact on rural and urban communities.

Background

Urban communities were the first recipients of streamlined electricity in the late 1800s. Cities were determined to be the most suitable economic option for the development of electrical infrastructure because of the large amount of customers per square foot. The first centralized power station was opened in 1882 in lower Manhattan and was called the Pearl Street Station ("History of Electricity," n.d.). Coal was transported to the Pearl Street Station via horse and wagon, and was then used to power jumbo steam powered engines to spin generators and generate electricity. Electricity was then distributed to consumers who lived within one square mile of the facility. Today, New York City generates 40% of all of New York State's electricity, but consumes around 60%. The gap is filled by supplemental generation facilities in upstate New York. The generated electricity then travels hundreds of miles to reach the consumer (Rueb, 2017). The major problem facing cities today is that the extremely high demand cannot be satisfied by the aging electrical infrastructure.

By 1930, most households in cities had basic access to electricity. In comparison, only one out of ten households in rural areas had access to electricity ("History of America's Electric Cooperatives," 2016). Rural communities were not seen as an economically favorable option for utilities to invest in. As a result, the government mandated the development of electrical infrastructure in isolated areas by the Rural Electrification Act in 1936, which initiated the development of local cooperatives (Beatrice & Us, n.d.). Currently, most rural communities have access to electricity through a local cooperative. Cooperatives are non-profit, customer-owned energy companies that deliver electricity to rural areas across the United States ("America's Electric Cooperatives," 2017). The existing infrastructure in rural communities is fragile and unreliable. For example, in 2016, customers experienced an average of 1.3 interruptions and had no power for 4 hours out of the year. Of the three utility types (municipality, investor-owned, and co-op), co-op customers experienced an average of 1.6 interruptions and had no power for 6.1 hours of the year ("Average frequency and duration of electric distribution outages vary by states—Today in Energy—U.S. Energy Information Administration (EIA)," n.d.).

In these sociotechnical systems, the customers in urban and rural communities in the United States are directly impacted by the actions taken by the government, utilities, and investors. Until 1996, the utilities were regional monopolies regulated by the federal government. They controlled the generation and transmission aspects of the electrical infrastructure, and the prices were set by the government. In 1996, FERC Order 888 deregulated certain regions of the United States, promoting competition and innovation to reorganize and update the electrical infrastructure and to bring more efficient, lower cost power to the Nation's electricity consumers (Litvinov, Zhao, & Zheng, 2019). This transition was a result of the deteriorating infrastructure and thus required public utilities to provide open access non-discriminatory transmission tariffs and costs. Most of the infrastructure had not been updated since it was originally built in the early 1900s, and was not able to handle the surge in demand for electricity. This change created a wide variety of sociotechnical systems across the United States that varied from federally regulated public utilities, private generation utilities, private transmission utilities, and cooperatives.

In 2017, the American Society of Civil Engineers rated the electrical infrastructure with a D+ in their infrastructure report card ("ASCE's 2017 Infrastructure Report Card," n.d.). It was also stated that electrical infrastructure needs was ranked third with an estimated need of $934 billion. As a result of the failing infrastructure, access to electricity has become unreliable. The lack of consistent electricity has been associated with multiple negative effects revolving around chronic and persistent poverty. Economic, health, and educational impacts resulting from an unreliable electric grid will delay the development and upkeep of community amenities, further damaging the community's opportunities for success. ("Energy Inequality—Conceptual Notes and Declarations—IIASA," n.d.).

Methods: Data Collection

A case study of two sociotechnical systems will compare urban and rural communities with respect to their electrical infrastructure. The reliability of the electric grid will be measured for each system. Then, each system will be evaluated to reveal the economic, health, and educational impacts of failing electric grids. The following metrics will be used to identify an urban node and a rural node to further study; average property size, people per square foot, GDP per capita, fertility rate, death rate, and average life span. Locational analysis using Social Explorer will be used to identify these statistics for possible nodal locations.

The reliability of the electric grid will be evaluated by measuring the security and the adequacy of the grid. The security of the grid is the system's ability to withstand stability in response to disturbances. The adequacy of the grid is the ability of the grid's supply to sufficiently meet the demand (Gu, Zhang, Ma, Yan, & Song, 2018).

The direct impacts of grid reliability will be measured by the length and frequency of power outages in urban and rural communities. Power outages are recorded and collected by the U.S. Energy Information Administration ("Annual Electric Power Industry Report, Form EIA-861 detailed data files," n.d.). Power outage statistics are also recorded and publicized by deregulated utilities. Therefore, more data can be acquired once the locations are chosen.

Methods: Data Analysis

Once the reliability of the local electric grid is measured for each node, the effects of the grid on its respective community will be analyzed using certain parameters. Three categories of impacts will be analyzed - economic impacts, health impacts, and educational impacts. Each impact will be measured over two periods of time - 1 week and 1 year. This will demonstrate the short-term and long-term effects of grid reliability. This will be repeated five times for each node, allowing for comparison within each node and between both nodes. Each node will be analyzed during the following five years (five trials); 1995, 2000, 2005, 2010, and 2015. As a result of this analysis, I will be able to identify trends of grid reliability within a community, and compare the impacts of grid reliability between two different sociotechnical systems.

The economic impact of power outages in an urban or rural area will be evaluated by measuring the losses due to industrial production interruption, the additional costs that users pay for reducing the impact of power outages and adjusting their activities, and psychological panic (Shuai et al., 2018).

The health impact of power outages in an urban or rural area will be evaluated by measuring the relative amount of hospitalizations and mortalities during a power outage in comparison to an average day (or specified time period) (Dominianni, Lane, Johnson, Kazuhiko Ito, & Matte, 2018).

The educational impact of power outages in an urban or rural areas will be evaluated by extrapolating the amount of lost instruction time, restriction of electronic resources, and reduced access to information. The amount of students affected will be determined by summing the school enrollments for each school that was affected by a power outage in that area ("This week's wildfires and blackouts have now kept nearly a quarter-million CA kids out of school," 2019).

Conclusion

Access to reliable electricity plays a large role in the development of a community. Communities across the United States have different histories, cultural norms, and political structures that all shape the function of their sociotechnical system. In my research, I would like to determine how the weakening electrical infrastructure, only one of those factors, affects each system. My research will show that alternative solutions to the United States electricity system are necessary in order to successfully address the variation of needs across the country. In addition, a process for identifying those needs will be created and standardized. This will enable engineers to address each problem independently and provide accurate solutions for each sociotechnical system.

My capstone project is working on developing a small-scale solution to this problem. Our product increases access to small amounts of electricity without relying on the electric grid. This solution was developed to solve the problem created by the technological revolution. The technological revolution has created a society that heavily depends on the availability of electricity in order to succeed. Electric powered devices are used almost constantly in everyday life, requiring consumers to have consistent access to power. The increased demand for electricity has created a need for technological innovations and alternative solutions, thus shaping the direction of the energy industry.

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