UVA Net-Zero Residence Initiative – Energy Generation

(Technical Paper)

The Web of the Grid

(STS Paper)

A Thesis Prospectus Submitted to the

Faculty of the School of Engineering and Applied Science

University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements of the Degree

Bachelor of Science, School of Engineering

Luke Anderson

Fall, 2021

Technical Project Team Members:

Luke Anderson

Jillian Doyle

Noah Plues

Joshua Starr

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

Signature: _____ | Date: _____

Luke Anderson

Approved: _____ | Date: _____

Dr. Harsha K. Chelliah, Department of Mechanical and Aerospace Engineering

Approved: _____ | Date: _____

S. Travis Elliott, Department of Engineering and Society

PROSPECTUS

UVA Net-Zero Residence Initiative – Energy Generation

(Technical Topic)

The Web of the Grid

(STS Topic)

Luke Anderson

November 23, 2021

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.

Signed: _____

Approved: _____ Date: _____

Dr. Benjamin J. Laugelli, Department of Engineering and Society

Approved: _____ Date: _____

Dr. Harsha K. Chelliah, Department of Mechanical and Aerospace Engineering

INTRODUCTION

On January 12, 2010, the Republic of Haiti was struck with an earthquake that killed over 300,000 and left 1.3 million homeless (Pallardy, 2021). The University of Virginia (UVA) School of Architecture responded with "Initiative Recover," a plan to build a house that could serve as a blueprint for future houses in Haiti (Ford, 2010, 2011). My team intends to upgrade the energy infrastructure of the "Recover" house. Our goal is to install solar tracking panels that produce enough solar power to heat and cool the house. Photovoltaic (PV) solar panels that track the Sun are a great source of clean energy.

The main feature of our project is its independence from the power grid. An off-grid design will allow our system to be implemented in disaster-relief settings without access to public power. Our grid-independent, battery-based energy system could also serve to heat or cool houses during a blackout. In February 2021, millions lost power and more than 100 people died during a blackout in Texas (American Oversight, 2021). These events are becoming more common as our aging infrastructure meets new threats posed by climate change. In the United States, "power failures have increased by more than 60 percent since 2015" (Flavelle, 2021).

The current approach has been to weatherize the grid. On June 8, 2021, Texas Governor Greg Abbott signed weatherization legislation into law, requiring power generation facilities, natural gas facilities, and transmission facilities to be capable of handling extreme weather (Office of the Texas Governor, 2021). However, weatherizing the existing grid will only add to the problem. According to a report by five former Texas regulators, "safeguarding the grid requires … acknowledging the realities of climate change" (Weber, 2021). Climate change will continue to cause extreme weather events that push the grid to its limits. Also, saying things like

“everything that needed to be done was done” encourages increased reliance on public power (Rosenthal, 2021).

The grid is a technology that has amassed momentum and influenced society in countless ways. We have become dependent on the grid; it is time to understand how that happened and what alternatives are available. I hope to use my study of the events in Texas to understand how we have come to rely so heavily on the grid.

TECHNICAL PROJECT

The first part of our project involves generating clean, renewable energy using solar panels that track the Sun. Our panels will be mounted in series on the roof. The tracking mechanism will rotate on one axis from East to West with the Sun. My team will test various designs for our solar-tracking mechanism until we arrive at the best design.

Trackers can be divided into two main groups (i.e., passive vs. active). Passive trackers are purely mechanical and do not consume electricity. They use thermodynamic principles (e.g., hydraulics or thermal expansion) to rotate the panel throughout the day. Because they must be sensitive to minute changes in weight, damping must be used to mitigate fluctuations in the environment. Active trackers, which use sensors, controllers, and actuators, are much more precise. They can come pre-programmed with solar path data or determine the direction of the Sun using sensors, such as photoresistors in an array.

Because the Sun is an intermittent source of energy, it becomes crucial to be able to store excess energy. The house already includes an existing array of stationary panels that charge a series of 12V lead-acid batteries. We will probably construct a separate storage and distribution system focused on powering our heat pump.

Heating, ventilation, and air-conditioning (HVAC) accounts for about half the average energy bill in America. My team will seek to improve the efficiency of residential HVAC systems by using ground-source heating, exchanging heat with Earth's crust. This process of taking advantage of the constant temperature of the ground can be 3 to 6 times as efficient as the average HVAC system. Our design will involve a modular, pre-packaged heat pump with loops of piping. A trench will be dug, and the slinky-like piping will be buried about 6 feet deep. We will need to determine how much separation is required between each loop to achieve effective heat transfer properties with the ground. For context, the average ground-source heat pump (GSHP) uses 600 feet of horizontal piping at a depth of 6 feet.

The final piece of our project will be insulating the house using eco-friendly materials. The first step is to seal any leaks in the floor, walls, ceiling, or roof to minimize heat exchange due to convection. The next step is to test and install the cleanest, most effective insulation material. We will study layering techniques to determine the best order of installation. Finally, we will study the effect of insulation placement. Is insulation more effective at preventing heat transfer when placed on the walls, floor, or ceiling? My team will research radiative heating and cooling methods as well, keeping in mind that such methods may not always be desirable. For example, shading may be wanted in the summer but not in the winter, when the house is already cold. We will use MATLAB and SolidWorks to model the effects of layering.

STS CASE STUDY

On February 12, 2021, Texas Governor Greg Abbott declared a state of emergency due to the severity of winter storm Uri. From February 15-18, 2021, the storm, caused by a polar vortex, forced the Electric Reliability Council of Texas (ERCOT) to shed load from the main electric grid in Texas, causing millions to lose power when they needed it most. On February 15,

2021, the frequency of the ERCOT grid fell below 59.4 Hz for 4 minutes and 23 seconds. Uri also impacted water, gas, and housing. “At one point, up to 12 million Texans were without water or under boil advisories due to either low water pressure or damaged treatment facilities” (A Committee of Faculty and Staff at the University of Texas at Austin, 2021).

The storm caused all types of generation technologies to fail. Snow and ice collected on solar panels and wind turbine blades. Water froze on its way to nuclear power plants, and natural gas froze in pipes. Some critical natural gas delivery equipment experienced power outages because the operators had failed to alert their providers that such infrastructure was critical. Other generators may not have met their temperature design criteria. Several companies have since filed for bankruptcy.

Unusually cold winters in December 1989 and February 2011 had similar effects on the grid. The Public Utility Commission of Texas (PUCT), which oversees the operations of ERCOT, published a report in 1990 which stated that “the combination of heavy demand and loss of generating units caused near loss of the entire ERCOT electric grid.” We saw the same thing almost happen in February 2021. In February 2011, the response from the government was to ensure “readiness for extreme weather events” (A Committee of Faculty and Staff at the University of Texas at Austin, 2021). This same problem-solving approach is being taken today. The problem with this approach is that it adds to the problem it is trying to solve.

As a society, we are overly reliant on the grid to meet our energy needs. The goal of my socio-technical research is to understand how we got here. Texas serves as an example to all regions that depend on large, centralized power grids. As technological systems, electric grids have grown larger and more complex. As a result of this growth, grids have become more centralized. The theory of technological momentum put forth by Thomas Hughes can help

analyze what happened in Texas. According to Hughes, “as [technological systems] grow larger and more complex, [they] tend to be more shaping of society and less shaped by it” (Hughes, 1994). Poor, urban Americans are especially dependent on the grid. Can renewable technologies, such as those described in my technical project, offer to reduce our dependence on the grid? If so, renewable energy could mitigate the deadly effects of blackouts or prevent them altogether. Is the technological momentum of the existing grid inhibiting the adoption of new technologies? These are the questions I will be trying to answer as I study the history of power grids in America.

CONCLUSION

My technical project is focused on providing the energy to heat and cool a house using rooftop solar tracking panels. Tracking the Sun gets the most out of each solar module, but most solar tracking mechanisms are too heavy to be installed on a roof. The broader socio-technical problem this technology will help solve is over-reliance on public power from electric grids. We have become so dependent on the grid that people die when they stop working. My end goal is to understand how the grid was developed and how we became so dependent on it. If I can understand how we got here, I can figure out what needs to be done to untangle ourselves from the web of the grid. The path to energy security probably involves more than just weatherizing the grid. In February 2021, when Texas lost 48.6% of its total installed capacity, our true dependence on the grid was revealed (Robb, 2021). I believe the technological momentum of the grid led many Texans to rely on its electric power to survive. It is time we look at alternatives to the main grid, such as backup solar power to reduce dependence and save lives.

WORD COUNT

1_646

REFERENCES

A Committee of Faculty and Staff at the University of Texas at Austin. (2021). *The Timeline and Events of the February 2021 Texas Electric Grid Blackouts.* The Energy Institute at the University of Texas at Austin.

American Oversight. (2021, May 12). *The February 2021 Texas Power Outage*. Retrieved from American Oversight: https://www.americanoversight.org/investigation/the-february-2021-texas-power-outage

Flavelle, C. (2021, July 2). *A New, Deadly Risk for Cities in Summer: Power Failures During Heat Waves*. Retrieved from The New York Times: https://www.nytimes.com/2021/05/03/climate/heat-climate-health-risks.html

Ford, J. (2010, July 1). *UVA Architecture School's "Initiative ReCOVER" Submits Housing Design For Haiti Reconstruction Competition*. Retrieved from UVA Today: https://news.virginia.edu/content/uva-architecture-schools-initiative-recover-submits-housing-design-haiti-reconstruction

Ford, J. (2011, January 13). *UVA Architecture School's "Inititative ReCOVER" Wins International Housing For Haiti Competition*. Retrieved from UVA Today: https://news.virginia.edu/content/uva-architecture-schools-initiative-recover-wins-international-housing-haiti-competition

Hughes, T. P. (1994). Technological Momentum. In L. Marx, & M. R. Smith, *Does Technology Drive History? The Dilemma of Technological Determinism* (p. Chapter 9). Cambridge, Massachusetts: The MIT Press.

Office of the Texas Governor. (2021, June 8). *Governor Abbott Signs ERCOT Reforms, Power Grid Weatherization Legislation Into Law*. Retrieved from Office of the Texas Governor |

Greg Abbott: https://gov.texas.gov/news/post/governor-abbott-signs-ercot-reforms-power-grid-weatherization-legislation-into-law

Pallardy, R. (2021, January 6). *2010 Haiti earthquake*. Retrieved from Encyclopedia Bitannica: https://www.britannica.com/event/2010-Haiti-earthquake

Robb, J. B. (2021). *Power Struggle: Examining the 2021 Texas Grid Failure.* Washington, DC: United States House of Representatives.

Rosenthal, Z. (2021, June 9). *Texas governor vows to 'weatherize' after deadly winter crisis*. Retrieved from MSN: https://www.msn.com/en-us/weather/topstories/texas-governor-vows-to-weatherize-after-deadly-winter-crisis/ar-AAKSmlj

Weber, P. J. (2021, June 8). *Texas governor says power grid fixed; experts cite problems*. Retrieved from ABC News: https://abcnews.go.com/Politics/wireStory/texas-governor-power-grid-fixed-experts-cite-problems-78161513