OPUS
College of Engineering
MARQUETTE UNIVERSITY
Electrical and Computer Engineering

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Department of

ELECTRICAL & COMPUTER

Engineering

OPUS
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SENIOR DESIGN PROJECTS

FOREWORD

from the Department Chair

On behalf of the Department of Electrical and Computer Engineering in the Opus College of Engineering, I would like to showcase our students' capstone senior-design course for the academic year of 2021-2022. These senior-design projects are incredibly important to our students' preparation as they become transformative engineers. I strongly believe that both education and research can benefit greatly from close partnerships with industry, and vice versa. Hence, the industry's sponsorship of these projects is key to both the success of the projects and the completeness of our students' education. The senior-design projects that our students carry out each year demonstrate how what students learn in their curriculum is put to practice.

As you glance through the projects in the following pages and read through the testimonials by students, you will see the evidence of the technical depth and breadth of our electrical-engineering and computer-engineering programs. This is remarkable. The subject matter of the projects also shows our students' commitment to positively impact industry and society at-large.

I would like to thank our faculty for their hard work planning, designing, and implementing a world-class senior-design course sequence. I am equally grateful to our students for their creative work, perseverance, and determination to serve their community and society.

Sincerely,

Majeed Hayat

Dr. Majeed Hayat
Professor and Department Chair,
Electrical and Computer Engineering

ABOUT

The Senior Design Projects

All senior year electrical and computer engineering students are required to complete this two-semester multidisciplinary course. The course requires students to work on a design project in a team of three to five students. While working on the design project, the students learn and practice current project management methodologies, including written reports, oral presentations and the development of a working prototype.

Several of these projects are sponsored by our industry partners, giving students an opportunity to peek into the real world, and gain experience and insights into various practices and technologies employed by industry.

As a special note, we'd like to thank Dr. Marek Trawicki, who has skillfully and excellently coordinated the Department of Electrical and Computer Engineering senior design projects.

SPONSORS

Mr. Todd Sinclair, Sin Emerging Technologies
Mr. David Nestler, WE Energies
Mr. Andrew Spaulding, Milwaukee Tool
Mr. Danny Hudetz, Privio
Marquette Energy Analytics
Mr. Frank Jacoby, Marquette University
Dr Jie Gao, Marquette University
Dr. James Richie, Marquette University

NEXT MIND

PROJECT TEAM:

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Joel Burkert
Dennis Burmeister
Andrew Leinauer
Samantha Munoz

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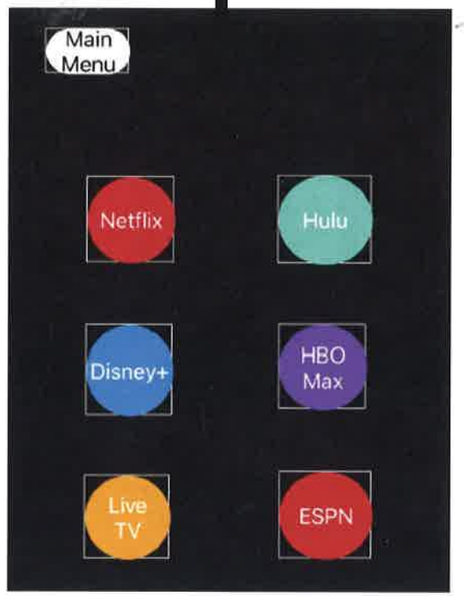
SPONSOR

Mr. Todd Sinclair, Sin Emerging Technologies



The Next Mind SDK uses a non-invasive EEG technology to detect electrical signals from the user's brain, as mentioned by the NextMind website. The eyes project an image from the Next Mind program on to the visual cortex (Nextmind.com). The visual cortex then decodes the location of the user's focus and relays the signal to the program or computer. The user's eyes not only project the image onto the visual cortex, but it creates a resonance with the object being focused on. The more the user focuses on the object, the stronger the neural activation surrounding that object, which is then relayed into a digital signal to the computer. The goal of this project is to discover the endless possibilities and capabilities of the Next Mind device while utilizing the program Unity. Due to the fact that this device has minimal research and documentation, the main purpose is to develop the documentation necessary to carry Next Mind to the next level and into new industries such as biomedical. The Next Mind has endless possibilities and industry applications. One of the major possible applications will be in the medical industry. It is known that it is extremely difficult for someone with mobility issues to be independent. This device could lead us down a path that increases independence for those with decreased mobility. For example, one who is bed-ridden may be able to control certain devices without the use of their extremities. The Next Mind has the potential to control any computer programmed device that has a visual stimulus present. This device can also be extremely useful in the control of prosthetics and improve the connection between one's brain and their prosthetic limb. Not only can the Next Mind be utilized for many biomedical applications, but this device can also drive the future in gaming. Currently, gaming is moving in the direction of virtual reality, but this device offers a new aspect to that industry. This device offers the possibility of control of the game without hand controllers. Instead, the player will control and manipulate their environment simply by their focus on a visual stimulus. This route is already being experimented by certain companies in the VR world, and applications will continue to be discovered.

FREE THROW AI

PROJECT TEAM:

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Justin Ethithara
Anthony Nicholas
Tyrell To
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FACULTY ADVISOR:

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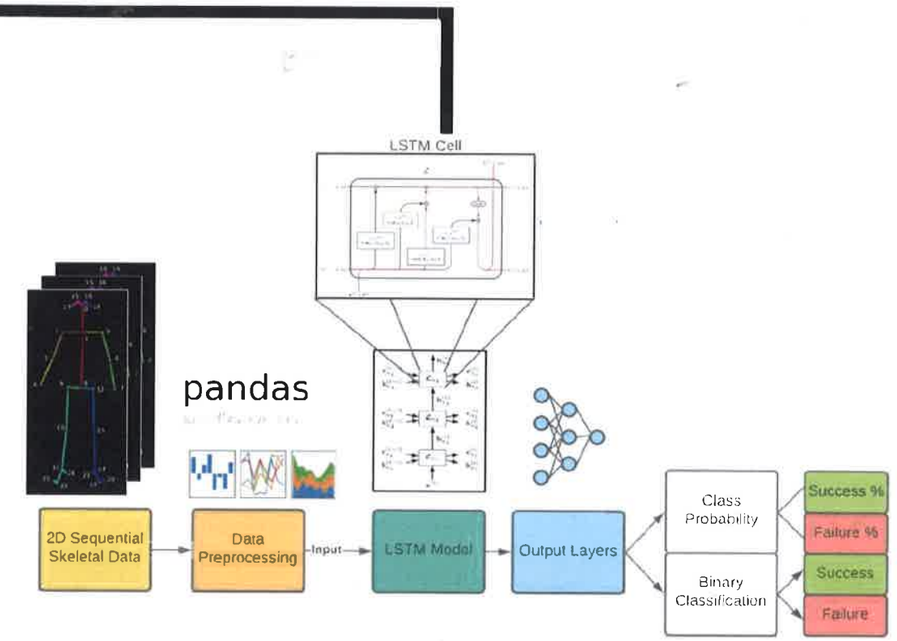
Mr. Todd Sinclair, Sin Emerging Technologies



As of 2021, the combined worth of all the teams in the NBA is estimated to be $66 billion. However, this number barely represents the true value of basketball as it does not factor in sources like college and overseas basketball. With this much value being thrown around, research surrounding the science in basketball has become a field in itself. One of the most prominent examples is understanding the elusive free throw. A free throw is a penalty shot performed 15 feet away in front of the hoop where a player can earn points for their team. With free points on the line, the free throw has become a valuable source of points for teams. However, the technique surrounding the shot has been scrutinized repeatedly, with people worldwide having their own opinions about what the best form actually is. Our team would like to provide players and coaches with a way to measure various aspects of a free throw by giving the probability of success upon each shot. With key data about a free throw form, our hope is to provide our customers with critical data to help make essential improvements to a player's shot. This problem is important to our clients because it provides our customers with an essential joint-based analysis of a person's free throw shot when successfully implemented. Our project objective is to design a program that, through machine learning, can identify the likelihood of successfully making a free throw based on skeletal-data body movement cues. The video data is collected using 1080p 30FPS cameras positioned around the subject as he or she shoots multiple shots. The team will analyze free-throw videos of numerous people and separate the data into two categories: make or miss. After successfully converting the data to a .csv file using the appropriate software, we can run it through the program and allow the system to learn and identify any body movement patterns that indicate whether the free throw attempt will be successful.

AUGEMENTED REALITY INSPECTION ASSISTANCE

PROJECT TEAM:

Mike Awadallah
Andrew Beugnet
Noah Broeski
Andrew Simon
Ryan Yang

FACULTY ADVISOR:

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SPONSOR

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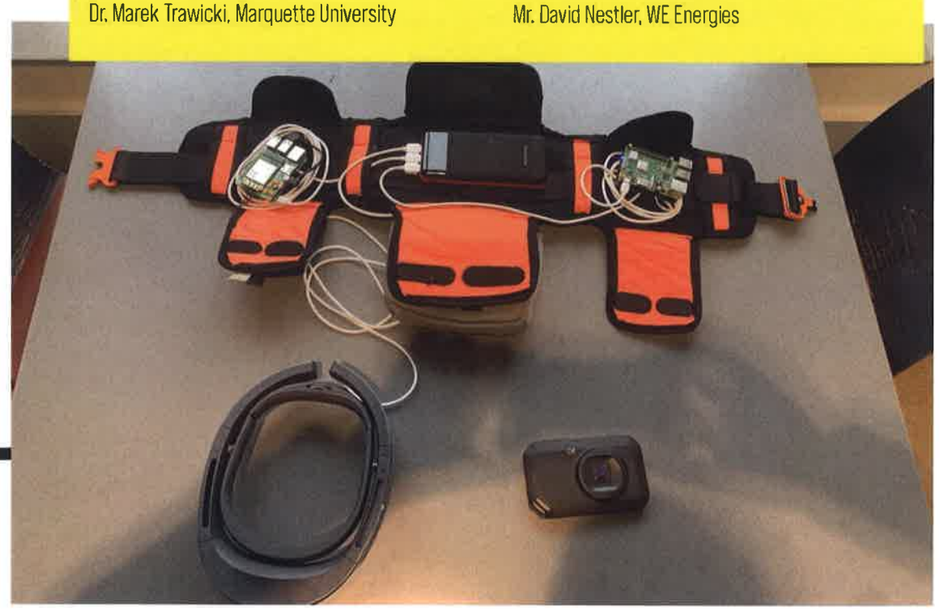

In totality, our job and the main goal of this entire project is to make the job of substation inspectors more streamlined, more automated, and most importantly, safer. As it stands, substation inspectors are tasked with "going beyond the fence" of high voltage electric system facilities and inspecting all aspects of it; from transformers all the way down to the fences themselves. Having to record everything they see via laptop or clipboard, the current processes are highly inefficient and can be extremely dangerous. By further developing the WEAR technology, we can offer substation inspectors a fully automated, hands-free way to streamline the entire process. Our target audience for this product would be field engineers and substation inspectors. With that being said, the product's primary use is to make the overall substation processes easier and safer. Every person in the workforce would benefit from having safer working conditions, and this product can provide that to all substation inspectors. Outside of our clients, this technology would be something that data analysts and engineers would be interested in. Looking past the physical hardware component of this project, this is primarily from a software aspect involved that can automatically collect and store substation data to backend data systems. This technology can be timesaving and labor-saving for data workers. As previously mentioned, this project is being tasked out and sponsored solely by WE Energies. If they were interested in going public or selling the rights to this technology, we don't see why a product like this wouldn't be sought after by all other energy companies in the United States and all over the world.
Substation inspections are something every energy company must do abd will never go away. Having technology that can make work easier and safer is something that will always be highly sought after. The current status quo for inspections is outdated and can cause unsafe work conditions. A better solution is necessary because the current processes are laborious and unsafe. Unsafe working conditions is something that is not tolerated at any level and needs to be changed if possible. On that same note, automating the current process can allow for quicker inspections, more efficient work, and less time workers have to spend in potentially dangerous areas. The primary objectives of the project are to expand on the previous design group's work of having the hardware and software interface with the Cascade system used by WE Energies and expand on the product's ability to make the inspection process safer and as hands free as possible. The data retrieved from Cascade will be used to inform field engineers and substation inspectors of relevant information about the substation, the different component areas, and work orders pertaining to any part of the substation. The augmented reality components of the project will otherwise be used to increase the efficiency and safety of the inspection process. The primary objective of this will be to use an IR camera and virtual representations of the normal inspection forms to inform the on-site worker of heated components and allow their focus to be on what they can see in front of them at all times while entering data.

PRIVIO COMMUNITY VOTING SYSTEM

PROJECT TEAM:

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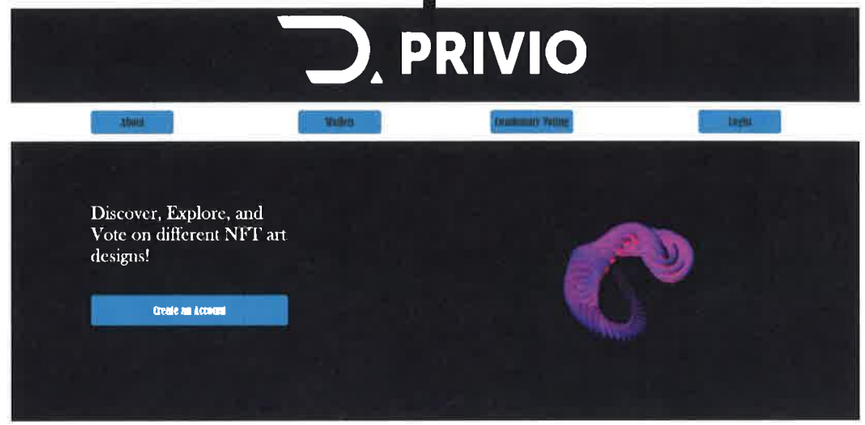
Sam Torti
Ramon Gonzalez
Danny Hudetz

FACULTY ADVISOR:

Dr. Marek Trawicki, Marquette University

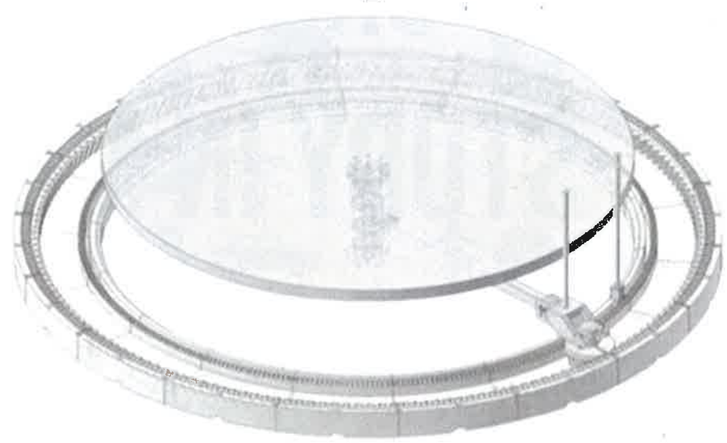
SPONSOR

Mr. Danny Hudetz, Privio



For this project, the team will be focusing on developing the blockchain protocol for strengthening the back end of PRIVIO's website. PRIVIO is in the process of developing a new NFT drop called a PRIV Key. The concept of the PRIV Key is to create a unique NFT identifier that can be recognized by the PRIVIO's database when logged in. The PRIV key is basically an NFT that acts as an identifier to the PRIVIO's database that opens access to the website. The problem that the team is specifically trying to solve is to create a community voting system on the blockchain. The team has to develop a method in which a PRIV Key enables a user to cast one vote on the website. An example of how this voting system could work is a few artists are picked to develop NFTs and present it on the website. The community then gets to vote on who has the best art. Each member containing a PRIV Key is granted one vote. Since the community can vote, the team wants their votes to be valid, and it will go through with the smart contracts. Smart contracts are what is measuring the community vote instead of humans calculating the vote. This is so that every vote will count and will be seen that their vote will be counted. Our client is PRIVIO, and this solution is important to them because the voting system can help build a strong and connected community. The voting asystem enables PRIVIO community members a fun way to interact with each other and the company. Another client whom PRIVIO will look towards are the owners of the NFT keys. Although the community is going to be big as it is, the community who buys NFT keys will be its own subset group this company will view as its client. The voting system also allows the company to incorporate many different features which creates a more vast and diverse community. Other than our customer/client, the team believes that other people working in blockchain technology and NFTs would be interested in having the ideas of PRIV keys. C44 also believes that companies who focus on blockchain technology would be interested in the technology aspect of this project, and would like to start having wallets or their own companies as well. With these PRIV keys, the community voting system will be useful with everyone voting per NFT. The voting system would also help websites using blockchain as its core technology. This research and ideas could help them within their company growth.

SCATTERED FIELD MEASUREMENT SYSTEM



PROJECT TEAM:

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Ted Nowak
Marina Monacelli

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Dr. James Richie, Marquette Uniyersity

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Dr. James Richie, Marquette University

Microwave imaging can be achieved by directing a pair of transmit-receive antennas to send and receive electromagnetic waves which interact with the environment or an object under test. By analyzing the sent and received waves, the group can reconstruct the boundary of the object for identification. In addition, the group can determine some of the material properties of the object. The overall goal is to develop a transmit-receive system that allows the group to capture electromagnetic waves which are scattered by a known object. The project sponsors can then use inverse scattering techniques to reconstruct an image of the object. As research in microwave imaging continues, it presents itself as an alternative to current imaging techniques as observed through simulations. As mentioned earlier, x-rays were the first to use electromagnetic radiation to image skeletal structures. While prevalent today, x-rays emit ionizing radiation which needs to be regulated to prevent tissue damage or other health issues. Computed tomography, or CT, also utilizes x-ray imaging to obtain high resolution images of the body. Other medical imaging techniques include magnetic resonance imaging and sonography. While MRI's also take advantage of non-ioninzing radiation, they are suitable for some individuals who may have metallic implants of some sort. Sonography is also used extensively in medical imaging and employs ultrasound to reconstruct internal images. Sound waves, however, do not travel at the same speed through all mediums, which can pose a problem for image reconstruction. This project can be used as a stimulus for further research and development in the emerging field of microwave imaging. It will serve as a continuance and application of theoretical research aimed at further understanding the capabilities of microwave technologies. Not only can microwave imaging provide a safer alternative to x-ray imaging, but it also has the possibility of expanding outside of biomedical applications and into a myriad of others such as food processing and manufacturing and search and rescue equipment. With such a vast realm of influence, microwave imaging has the potential to be better understood by the successful completion of the proposed scattered field measurement system project.

EV CHARGING STATIONS STUDY IN MILWAUKEE

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David Lyke
Clyde Hollister
Jack Land
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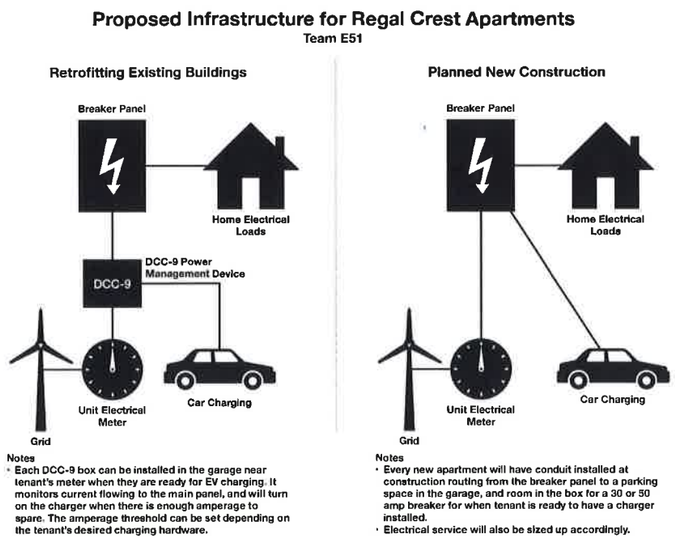
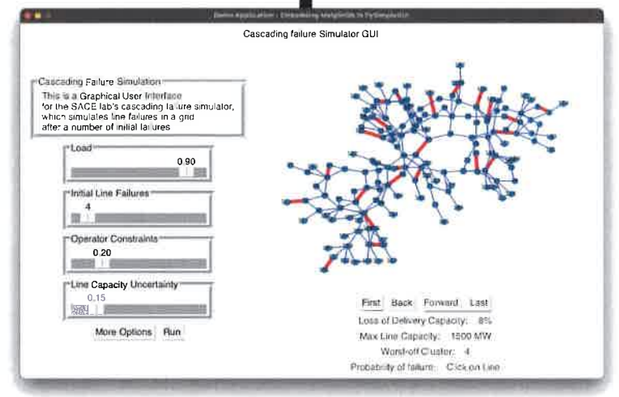


As the number of electrical vehicles increases, the ability and needs for charging services arise. With a dramatic influx anticipated, there will be a growing demand for at home charging, and we are targeting how to capitalize on this market with existing structures within Milwaukee apartments that could possibly implement a charging solution for multiple electrical vehicles by utilizing an analysis of the market and the costs to implement these charging stations. We are trying to provide a resource for potential clients that seek a method or way to the solution of the growing Electrical vehicles market and the services that come with them (such as charging stations). To capitalize on this market's potential, we are supplying information on how property managers and the like can provide an essential, effortless service for their customers. Our customers would be the property managers and our solution for them is important as it can provide the necessary technical nuances that arise when trying to implement charging onsite of their properties and the costs that may be associated with it for the future of growing populations of electrical vehicles and how taking steps for the future of this market would be in their benefit. As electric vehicle owners become increasingly common, there will be increased demand for ease of access to charging. Charging an electric vehicle is a hassle you sign up for when making the switch. Whenever a market expands, it will naturally begin to correct itself. Part of that correction is going to be ease of access. Our solution is getting a jump start on a problem that will only become more apparent. The convenience of electric charging stations in living spaces as well as the workplace will sell itself. For there to be said smooth transition to electric vehicles and a larger incentive for consumers to get into the market, there must be the necessary infrastructure in place to make their switch to electric vehicles feasible. One of the largest concerns around electric vehicles when they are being considered, as opposed to an internal combustion vehicle, is the ease of charging. This ease embodies two major factors, the access and location of chargers and the time to full charge. One of the most cost-effective ways to address both issues is to implement level 2 charging stations in locations where vehicles will be parked for extended periods of time, such as residential parking structures or places of work.

A COMPLETE TOOL FOR ANALYZING AND DETECTING CASCADING FAILURES IN ELECTRIC POWER GRIDS



PROJECT TEAM:

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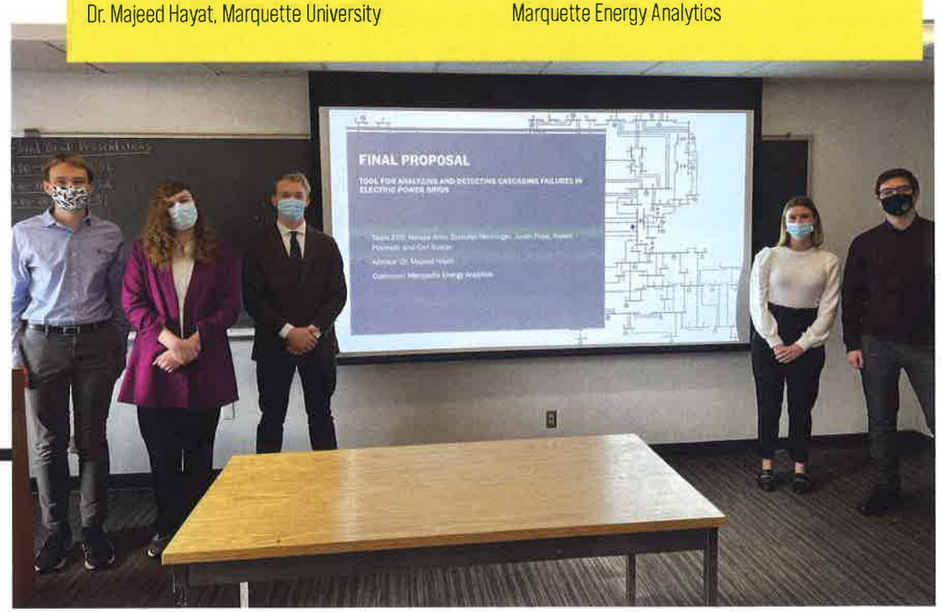
Brendan Nenninger
Justin Popp
Kassie Povinelli
Carl Sustar

FACULTY ADVISOR:

Dr. Majeed Hayat, Marquette University

SPONSOR

Marquette Energy Analytics



Failure of single lines in the power grid often does not lead to blackout as power is routed through alternate lines to its destination. However, this additional load on other lines can cause them to fail as well potentially causing a cascading blackout. Failures can be caused by natural disasters, electromagnetic pulse attacks, and cyber and physical attacks on the grid. For example, in 2003, the failure of four power lines due to contact with trees led to a cascade of failures and a blackout for 50 million people in the northeastern United States and southwestern Canada. The sequence of line failures is challenging for grid operators to forecast, but there are research efforts to create simulations that can predict the behavior of a power grid in a cascading failure scenario. The current simulator software developed by the Marquette SACE Lab can calculate much of the needed data for simulating cascading failure, but the simulator is difficult to use without deep knowledge of both cascading failures and the simulator itself. Other simulators have been built by researchers, but they have many of the same problems, or are simpler simulators that do not simulate cascading failure conditions or the physical aspects of the grid. It is difficult to determine if failures in an electrical grid will cascade to a blackout with power redistribution after line failures sometimes overload other lines. The SACE lab uses a physical electric grid simulation in MATLAB alongside a Markov Chain simulation to generate useful information in predicting the behavior of a grid after initial line failures. This tool, however, is impractical for users outside of the lab because it requires in-depth knowledge of grid dynamics, how the simulator works, and hard-coded values for simulations. Customers of Marquette Energy Analytics (MEA), the SACE lab, and other research labs require a grid simulation tool which is more user-friendly and more robust in the information it can show. A better solution is needed to create a user-friendly interface that provides forecasting for grid performance and the limits of the grid. This is significant as the Unites States power grid is aging and many failures particularly due to climate change are not able to be accurately predicted. The simulation must include accurate and fast probability results. The solution will need to provide useful data to operators in forecasting to aid in managing the grid. A better solution will also include a visualization – such as a heat map – to show the areas at highest risk of a cascading failure, giving customers the information they need to improve electric power grids.

SATELLITE NETWORKS COMMUNICATION SIMULATION

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Alex Huynh
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Dr. Jie Gao, Marquette University

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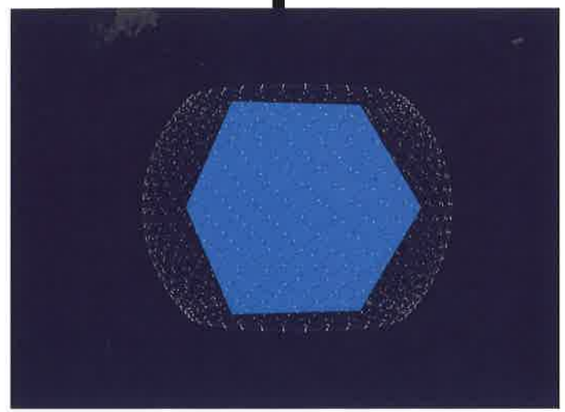

As internet and communication networks continue to advance, the potential for satellites to be integrated for seamless internet access cannot be ignored. Large constellations of satellites that are capable of transmitting data between two points using inter-satellite routing strategies can be used to cover much larger parts of the earth than the traditional tower system that is widely used today. In this project the concept is to simulate a system including many satellites with high-throughput to implement a network featuring dynamic topology, ground-to-satellite access with an automatic routing strategy to deliver the data from one point to another as fast as possible. This solution would greatly help companies that are currently trying to provide high speed internet connections to as large of an area as possible, without relying on dense networks of cell towers. Although these companies are the main target of this project, the customers of said companies, especially those in areas where cell towers are sparse, would be very interested in this as well. With the commercial implementation of 5G, communication networks can support new technologies including industrial automation, smart cities, and autonomous vehicles. While 5G has a high data rate and a low delay, it relies on dense connections with cell towers. In areas where cell towers are sparse, adequate network coverage remains a bottleneck. A system with increased coverage could positively impact areas such as environmental monitoring, search and rescue, smart agriculture, education access, and many more. This could be achieved through a large satellite network. Satellite communications have existed in broadcast (Satellite TV, radio, GPS) and bi-directional (satellite phone) forms. As well, companies like Starlink, OneWeb, and O3b are investing in satellite constellations to bring widespread network coverage. These current solutions lack configurable simulations which would properly model future satellite networks. Current cell towers are low range and require a dense network to provide consistent connection everywhere. Customers must have consistent connection everywhere with enough speed to use over traditional satellite internet and 5G solutions. This requires global connections and a routing algorithm that efficiently transports data across the globe. The simulation of the network must take delay constraints and load balancing into consideration and have configurable simulation variables to work at a higher level than solutions that already exist. Solutions to this problem already exist; however, they are proprietary and currently too simple to completely solve the problem. Current systems lack the ability to effectively route information, balance loads, and do not include a fully configurable simulation. This functionality is necessary to create a functioning satellite network that is useful to companies interested in implementing a satellite network beyond simulations.

POTENTIOSTATIC BATTERY CELL TESTER

PROJECT TEAM:

Brett Angiolo
Mateo Alvarez
Sal Gonzalez
Zach Bishop
Anthony DeFelippis

FACULTY ADVISOR:

Dr. Marek Trawicki. Marquette University

SPONSOR

Mr. Andrew Spaulding. Milwaukee Tool

The solution to this project requires the team to determine accurate measurements of self-discharge currents from a battery cell through the creation of a test-fixture. This discharge occurs naturally over the lifetime of the cell and results from a small amount of the internal chemical reactions occurring without any load connections to the cell. The value of this current is minute (5-6 microamps in a healthy cell), so the team needs to investigate a reliable and cheap way to accurately measure the self-discharge current. Measuring small currents means there needs to be a very stable and accurate DC power supply. Being able to accurately match the voltage of the battery cell is critical in measuring the self-discharge current.

TESTIMONIALS

"Senior design was the perfect place to combine the hard and soft skills I learned at Marquette with my personal experiences to work on a real-life problem and produce tangible results. My amazing team and I were able to define and execute a complex project on our own, with help from industry experts as well as our professors. Additionally, the two-semester project illuminated all the additional roles of an engineer that aren't always talked about in the classroom, from ideation through de-risking, design and prototyping, to giving professional presentations. This project gave me the insight and validation that I was headed in the right direction for my career!"

- DAVID LYKE

"Senior design has been one of the most vital learning experiences of my college career. It not only taught me how to successfully collaborate with teammates of various backgrounds, but it also prepared me for my future career in industry. Senior design exposed me to many important engineering concepts such as customer needs, target specifications, prototypes, and much more. Overall, it was a great experience that has prepared me for my future engineering career more than any other class or experience."

- SAMANTHA MUNOZ

FACULTY

Advisors

Hayat, Majeed, Ph.D.
Chair & Professor
Dynamical models for interdependent cyber-physical systems, Signal and image processing, Performance modeling of heterogeneous distributed computing systems, Statistical communication theory, Avalanche photodiodes, High-speed optical receivers, Probability and stochastic processes

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Werner Endowed Chair and Professor
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Ababei, Cristinel, Ph.D.
Associate Professor
Network-on-chip based multicore processors and datacenters, embedded systems, FGPAs, distribution networks and smart buildings

Gao, Jie, Ph.D.
Assistant Professor
Protocol design for future wireless networks, Machine learning for communications and networking, Internet of things (IoT) and industrial IoT, Connected and autonomous vehicles, Could and mobile edge computing, Multiagent systems and cooperative communications

Coutu, Ronald, Jr., Ph.D.
V. Clayton Lafferty Endowed Chair and Professor
Microelectromechanical systems (MEMS), advanced microsystems, device fabrication , chemical sensors

Josse, Fabien, Ph.D.
Professor
Solid state and acoustic wave sensors, MEMS devices and sensors, Optical waveguide-based sensors, Smart sensor systems

Demerdash, Nabeel, A.O., Ph.D.
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Lee, Chung Hoon, Ph.D.
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FACULTY

Advisors

Medeiros, Henry, Ph.D.
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Machine Learning, Signal Processing, Dynamical Systems and Chaos

Richie, James, Ph.D.
Associate Professor & Associate Chair
Electromagnetic scattering and inverse scattering, Antennas and wave propagation, Numerical techniques in electromagnetics

Schneider, Susan, Ph.D.
Associate Professor and Director of Undergraduate Studies
Modeling, analysis, estimation, and control of linear and non-linear systems, Applications of control and signal processing to sensor systems, Evaluation of the electrical properties of materials for use as sensors, Educational methods - novel pedagogy and assessment, Fireworks ballistics simulation and experiments

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Bioacoustics, Machine Learning, Mathematical Models, Natural Language Processing, Pattern Recognition, Speech Enhancement, Speech Recognition, Statistical Signal Processing

Weise, Nathan, Ph.D.
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Yaz, Edwin, E., Ph.D.
Professor
Stochastic, non-linear, and uncertain systems, signal processing, networked control systems, gender issues in STEM education

Ye, Dong Hye, Ph.D.
Assistant Professor
Machine Learning, Image Processing, Biomedical Image Analysis, Computed Topography, Metal Artifact Reduction Microscopic Imaging, Automatic Target Recognition, Unmanned Aerial Vehicle Detection/Tracking

OPUS COLLEGE OF ENGINEERING

Since 1908, the Marquette University Opus College of Engineering has been uniquely blending professional engineering preparation with a liberal arts education to provide the world with well balanced leaders in their profession.

MISSION

The mission of the College is to excel in four critical areas:

- To prepare all students for successful careers based on a strong moral and ethical foundation
- To advance the state-of-the-art in engineering
- To serve our professional and technical communities
- To contribute to our global society

ACCREDITATION

All undergraduate programs offered by the Marquette University Opus College of Engineering are accredited by the Engineering Accreditation Commission of ABET, 111 Market Place, Suite 1050, Baltimore, MD 21202-4012, 410-347-7700.

MARQUETTE UNIVERSITY

Founded in 1881 in Milwaukee, Wisconsin, Marquette University has been educating people of faith to be leaders in their professional lives, their communities and in society.

Since the first graduating class of five men were awarded bachelor of arts degrees in the 1880s, Marquette has grown into a modern coed campus of more than 11,000 students who learn and grow through nationally admired undergraduate, graduate and professional programs.