

EE476 Projects

Name:

Project Requests

NAU ID:

Over the next two Fridays, you will hear from most, if not all, of the project client sponsors. From these, you will need to consider which project you would like to work on. Due October 13th at midnight (11:59pm to be exact), you will need to upload a document outlining your top 5 preferences for projects. You are also required to tell me why you want these projects, but in no more than 5 sentences total. From these requests, I will assign teams, though please understand your request is just one factor in deciding exactly which project you will be working on.

Submit your requests via BBLearn only! A link for this assignment will be opened on October 12. So start thinking about what projects you would like to participate in, but know that you cannot submit this until you have heard from all the sponsors.

Table Top Doppler

EE Capstone Project

Your Client

Doppler radar is a highly effective tool for assessing such things as weather. However, most doppler systems are large - far from portable. Here, Drs. Willie and Chrysler are interested in creating a small table top doppler radar that operates at the Ka frequency 35.56GHz. A table top doppler, which is light and portable, could prove to be game changing for the meteorological sciences.

This project will result in a functional radar that should be able to measure velocity of objects and hopefully measure wind velocity. It will allow future students to physically see and better understand the concepts of electromagnetic wave propagation and the doppler effect. To buy a radar is way too expensive, but with some direction, senior students should be able to construct one.

Prototype Milestones

This project will adhere to the capstone class milestones.

Project Features

1. The radar must be able to transmit a continuous wave signal.
2. ... must be simulated in ANSYS HFSS or CST Microwave Studio.
3. ... must be able to receive a signal.
4. ... must separate transmit and receive.
5. ... must utilize an impedance matched network between the antenna and signal generator (exact SWR requirement up for discussion).
6. ... measure the doppler shift due to a moving object.
7. ... must create a display that shows operation in real time.
8. ... must obtain a range of 1km.
9. ... should be able to transmit a pulsed wave.
10. ... should be able to rotate on a pedestal.
11. ... should measure wind velocity field in real time.
12. ... ideally able to transmit vertical, horizontal polarization.

Project Success

The product should be small enough to fit on a table and compact enough in order for one person to move it. It should be able to operate outside, so some environment considerations need to be addressed (rain, dust, strong wind).

Satisfaction Standards

Exemplary - The project results in a small compact radar that can transmit and receive a continuous wave, and is able to determine the velocity and range of moving objects. A visual display would show the measurements in a meaningful way.

Good - The project produces a functional, transmitting and receiving, radar system that is able to measure velocity of an object, but that has no visual display.

Fair - The radar system is only able to transmit or receive. There is no way to determine velocity

Poor - Parts of the radar are assembled, and maybe even somewhat functional, but the radar is unable to transmit or receive a signal.

Special Team Skills

This project will entail signal processing, wave form generation, electromagnetic wave guide, antenna design, and coding to put together a display.

Specialty Equipment

The team will need to have access to a network analyzer that measures up to 40 GHz to measure the generated signal and possibly an anechoic chamber to measure the antenna pattern of the antenna. The network analyzer may have an option to borrow or rent. Or, the students might contact ASU to visit the range there. At the very least, the antenna should be measured on a Network Analyzer. An exemplary team would also measure the radiation pattern.

Instrumented Bike Share

EE Capstone Project

Your Client

“Instrumented Bikes are a new, innovative field. They are built on the concept that cars use a variety of sensors built inside smart phone to gather data about the environment and focus on extending this idea to bicycles in order to analyze and report trail conditions. As transportation and the use of infrastructure increases, it is becoming imperative that the conditions of roadways and trails unreachable by cars are assessed. Utilizing the popularity and prevalence of the Internet of Things in modern society, and this technology provide the network and platform to connect physical devices. Through use of microprocessors, sensors, and software, Instrumented Bikes communicate and exchange data between users. The information collected from this process is used to analyze and detect bumps in roads as well as assess infrastructural needs. To accomplish this, this technology uses microprocessor, sensors, the cloud, and a mobile platform[.]” - From Qiu et al, The Development of an IoT Instrumented Bike: for Assessment of Road and Bike Trail Conditions.

The objective of the capstone project is to develop instrumented bicycles that will be used to collect real-time information of infrastructure systems (corridors, bike roads, sidewalks, pedestrian paths, etc.), analyze field data, exam their quality, and provide recommendations to decision makers for improving the efficiency and ubiquitous use of bicycle mobility. A sensorized data logger system will be developed in the project. The data logger will consist of an inertial measurement unit (accelerometer and gyroscope), Global Positioning System (GPS), wireless network adapter (wifi), microSD card data storage, and a battery. A Go-Pro will be connected with the data logger attached on the instrumented bicycles to capture images while cycling.

We will use these instrumented bicycles to travel along pathways on campus, particularly locations where motor vehicles cannot access, to evaluate the capability and effectiveness of instrumented bicycles to record the measures needed to characterize infrastructure system status and quality. A group of volunteers will be invited to participant in road tests using the loggers developed in the project. All volunteers will travel on the same road path to allow us to evaluate whether vibration signatures resulted from different bicycles would be significant. Our hypothesis is that the data difference among all bicycles is not significant. The data collected from the field tests will be used to evaluate the statistical effect of sensor systems on a variety of bicycles and to address the concern from the industry that riders and bicycles would have significant vibration results that influence the accuracy of bike mobility on surface condition assessment.

Prototype Milestones

Last year, the student on this team wrote and presented a paper on their project at the IEEE ISSI Conference in China. This year, Drs. Jun Ho and Kyle N. Winfree are considering other venues as well. There may be deadlines for paper / poster submissions that are not yet known by the team. All publications will be strongly encouraged, though these will not be part of the grading scheme.

Project Features

1. The resultant product from this project must provide automatic recording of accelerometry and geospatial location to internal memory.
2. ... must have automatic detection of WiFi access, and offloading of the data via WiFi to a centralized server.

3. ... must provide processing of trail characteristics from said data.
4. ... should provide automatic identification of changes to the trail characteristics, representing a change needing maintenance attention.
5. ... should communicate with other cyclists to relay trail hazards.
6. ... should utilize a Smart Phone App to connect to any given bike with the available hardware (like the Orange Bikes or Bird Scooters).
7. ... ideally has a web dashboard that identifies trail conditions on a map overlay.

Project Success

This project will be successful if the results build on all previous research to form a fully functional system that could be deployed on the NAU Bike Share bikes.

Satisfaction Standards

Exemplary - All hardware is functional with software that enables easy use by any bike share bike user. Data collected from all bikes is saved to a centralized server where the researchers are able to perform export and analysis.

Good - A functional system is together, which works with specific phones, but isn't ready for deployment on the NAU campus.

Fair - Parts of the system are functional, but not as a unified system.

Poor - Parts of the system are functional, but only with the help of a human in the loop. For example, things are not packaged to be a self contained unit, but the parts work fine with a bench top power supply on hand.

Special Team Skills

This project will require some hardware fabrication, and some app development.

Specialty Equipment

A bicycle will be provided by the research team.

Project Title

Prototype Converter Development for Fast Charging of Electric Vehicles

Clients

Dr. Venkata Yaramasu

Assistant Professor of Electrical Engineering

School of Informatics, Computing and Cyber Systems (SICCS)

Tel: 928-523-6092

E-mail: Venkata.Yaramasu@nau.edu

Dr. Truong X. Nghiem

Assistant Professor of Electrical Engineering

School of Informatics, Computing and Cyber Systems (SICCS)

Tel: 928-523-4973

E-mail: Truong.Nghiem@nau.edu

Project Funding Source

Salt River Project (SRP), Phoenix, AZ

Project Location

Advanced Motors, Power Electronics, and Renewable Energy (AMPERE) Lab (Room: 090-101)

Project Description

The electric vehicle (EV) technologies are the most likely replacement to conventional internal combustion engine vehicles. This statement is supported by studies highlighting the benefits of a strong penetration of EVs in the transportation fleet particularly as we move toward cleaner electricity generation. According to the Department of Energy (DOE) report, a 400% growth in annual sales of EVs is expected by 2023, which will substantially increase electricity usage and peak demand in distribution grids. When clusters of EVs charge simultaneously, the distribution power network might not have the adequate capacity to accommodate the additional electricity

demand. This scenario will overload the distribution transformers, incur costly infrastructure to meet the peak charging demands, and incur higher operating costs for charging stations.

The architecture of EV charging stations is shown in Fig. 1, where a single ac-dc stage provides a common dc bus. This dc bus feeds several battery chargers and provides a more flexible structure, which can easily integrate distributed renewable energy conversion systems, and energy storage devices, since these systems are essentially dc. The central ac-dc stage can support the grid for voltage and frequency regulation. Existing charging stations (Fig. 2) are not equipped with energy generation and storage units. With energy generation and storage systems, charging stations will act as intelligent systems and provide an additional degree of freedom to perform secondary services such as energy arbitrage, standalone operation in case of grid faults, and other grid ancillary services (e.g., load leveling, power pulsation minimization, frequency regulation, reactive power control, etc.).

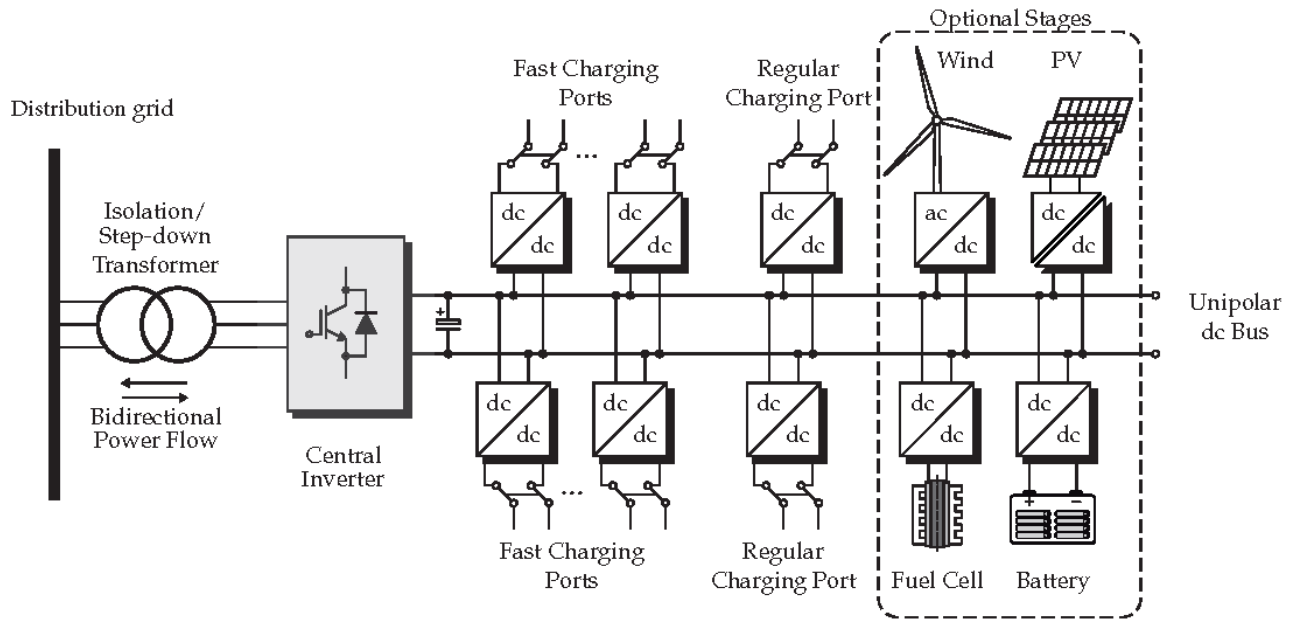


Fig. 1 Configuration of EV charging stations.



Fig. 2 TESLA supercharge EV charging station (Image: TESLA).

The problem we will address is the analysis of impact of deeper EV penetration on distribution transformers in the future distribution grids and smart grids without renewable generation and storage. The operation of the central converter for frequency regulation and reactive power control of local distribution grid will be analyzed with respect to different EV charging demands. The theoretical and simulation works will be validated by experimental tests using low-power (5 kW) charging station and fast charger prototype converters that will be developed in AMPERE laboratory.

Secondly, we will study the mitigation of negative impacts of deeper EV penetration in distribution grids. We will develop optimization models that will reduce operational costs of charging stations by shifting energy consumption from high to low priced periods. We will also study the economic aspect, such as payback period, of incorporating PV generation and energy storage in charging stations.

Knowledge, Skills, and Expertise Required for this Project

- Must have completed or currently pursuing one of the following senior power courses: EE380 Fundamentals of Electronic Circuits, EE401 Power Systems, EE402 Wind Power Conversion, EE403 Electric Drives, EE484 Power Electronics.
- Proficiency with MATLAB/Simulink software and SimPowerSystems Toolbox for simulation
- Proficiency with PCB design softwares such as Altium or OrCAD
- Proficiency with soldering and hardware development
- Ability for dSPACE-based rapid prototyping for digital control
- Abilities to research the power system market, electric vehicles, and battery energy storage.

Project Deliverables

Develop low-power (5 kW) hardware prototypes for central ac-dc converter, fast charger converter, and converters for battery energy storage. An example of prototype converter is shown in Fig. 1.

- The first task is to develop ac-dc central converter station using discrete semiconductor devices, gate drivers, passive components, voltage and current sensors, and control platform. The charging and grid support functions will be verified experimentally.
- The second task is to develop dc-dc converters for EV fast charging and battery energy storage. The hardware components used for this converter are similar to the central ac-dc converter. The performance of fast chargers and energy management strategies will be verified experimentally.

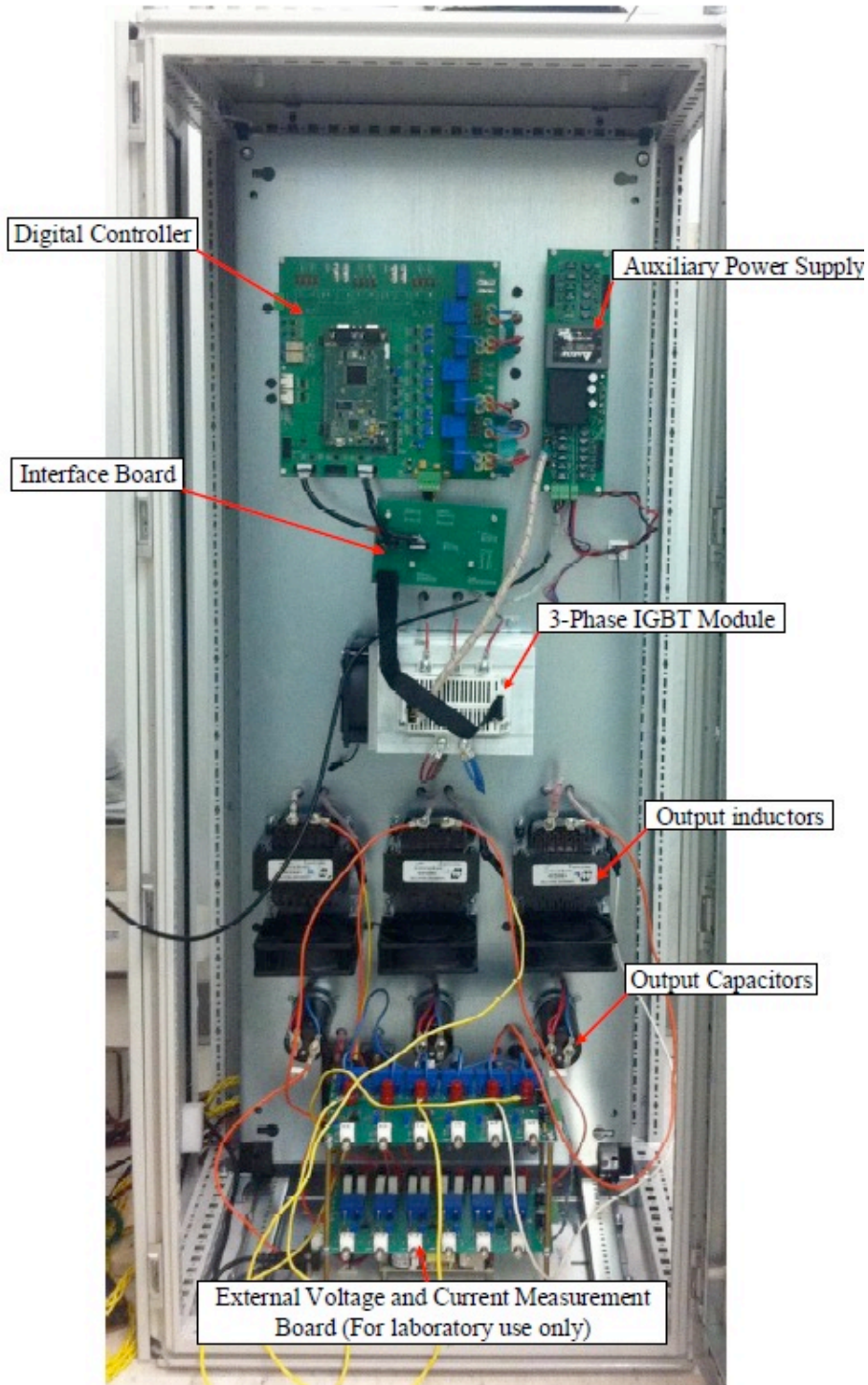


Fig. 1 Anticipated Prototype converter for this project.

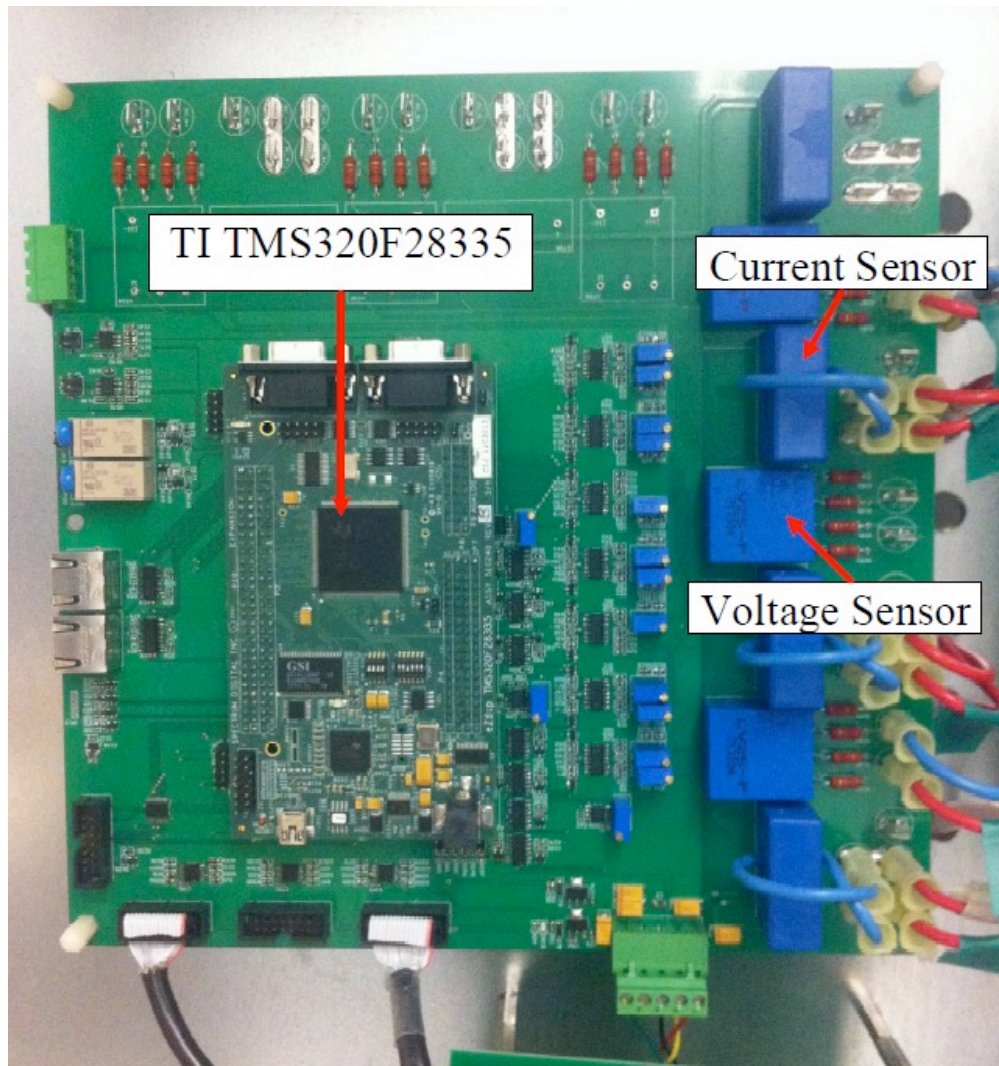


Fig. 2 Anticipated controller board for prototype converter.

Project Title

Analysis on Impacts of Zero Net Energy Homes and Electric Vehicles on Distribution Grids

Clients

Dr. Venkata Yaramasu

Assistant Professor of Electrical Engineering

School of Informatics, Computing and Cyber Systems (SICCS)

Tel: 928-523-6092

E-mail: Venkata.Yaramasu@nau.edu

Dr. Truong X. Nghiem

Assistant Professor of Electrical Engineering

School of Informatics, Computing and Cyber Systems (SICCS)

Tel: 928-523-4973

E-mail: Truong.Nghiem@nau.edu

Project Funding Source

Salt River Project (SRP), Phoenix, AZ

Project Location

Advanced Motors, Power Electronics, and Renewable Energy (AMPERE) Lab (Room: 090-101)

Intelligent Control Systems (ICONS) Lab (090-104)

Project Problem Statement

The state of California has set goals to achieve Zero Net Energy (ZNE) in new buildings with photovoltaic (PV) installation, for residential buildings by 2020, Government buildings by 2025, and commercial buildings by 2030. As a consequence, high PV penetration is likely to occur in geographically concentrated areas and impact local distribution systems. Studies conducted by Electric Power Research Institute (EPRI) and Southern California Edison (SCE) on Meritage homes indicate that the load profiles of ZNE homes (Fig. 1) have the duck curve at

single home level. In particular, the usage of energy of these homes will be substantially lower during morning times and backflow of energy will be higher. Their peaks loads will be shifted from afternoons to late evenings, creating steep evening ramps. The load shape also changes with the season (spring, fall, winter, and summer). In addition, appliances in these ZNE homes will be predominantly electric, as gas driven loads are electrified to utilize solar electricity generation, which further stress distribution systems during peak times. **In the state of Arizona, utility grid planners are not yet familiar with the impacts of ZNE communities on the local distribution transformers, load blocks, and feeders. No studies are available if Arizona is to follow California's bold plan of ZNE homes.**



Fig. 1 Concept of ZNE homes (Image: CREED LA)

In the future ZNE communities, electric vehicle (EV) technologies (Fig. 2) will have strong penetration, particularly as we move toward cleaner electricity generation. According to a Department of Energy (DOE) report, a 400% growth in annual sales of EVs is expected by 2023. The electrification of residential loads and EVs will substantially increase electricity usage and peak demand in distribution grids. It is expected that electrified loads will increase the peak load from the 6-10 kW range by another 9 kW, and if EV and storage are counted as loads that adds an additional 12 kW. **We (clients) find no relevant technical studies in the literature to analyze the simultaneous impact of ZNE homes and EV chargers on the distribution grids in Arizona.**



Fig. 2 EV charging station concept (Image: Microgrid Knowledge)

The past five years have seen considerable growth in grid-connected deployment of residential battery energy storage (Fig. 3). Depending on the price policies, the energy storage can either benefit or harm the distribution grid. The present Time-of-Use rates are designed for customer cost benefits, and they will not address duck curve in near future. A future implementation of ZNE homes will require energy storage systems be grid optimized so that they charge in the mid-morning hours and discharge in the evening period. **This project aims to study how optimized energy storage at consumer and distribution levels could reduce peaks and valleys in duck curve, while benefiting both consumers and utility operators.**



Fig. 3 Residential energy storage (Image: Tesla)

Project Goals

This project has two primary goals: (1) study the load profiles of ZNE homes during different time frames and their impact on distribution grids in Arizona; and (2) develop optimization algorithm for energy storage system to ensure that distribution transformers are not overloaded during backflow of energy in morning and peak loads in evenings.

To meet our first goal, we will characterize load profiles of ZNE homes and EVs and their impact on local distribution systems. We will study end-use load shapes and customer preferences using device data. Mathematical and simulation models will be developed to analyze the negative effects of ZNE homes with significant electrical loads and EVs. This study will focus on the distribution transformers and feeder overloading with respect to different PV generation and storage capacities.

To accomplish the second goal of this project, we will study the mitigation of negative impacts of deeper ZNE homes and EVs penetration in distribution grids. We will develop a generalized optimization model to study the impact of ZNE electrical loads, PV generation and storage systems on the distribution grid and transformers during normal and peak load demands. Optimization of this model will help reduce operational costs of ZNE homes and EV charging by shifting energy consumption from high to low priced periods.

Project Deliverables

The deliverable of the project is a report to clients and SRP documenting the impact of ZNE homes and EV charging on distribution grids. The report will answer the following basic questions:

1. In the SRP operating areas, how ZNE communities with high PV penetration and electrification (including EV charging at homes) could impact electrical distribution systems in an “as-is” scenario?
2. How emerging technologies with connected end loads and customer side storage (and also with utility level storage) can be used to balance high PV penetration and load peaks?
3. How to develop end-to-end modeling approach that integrates ZNE home modeling and energy storage into distribution system modeling and improve modeling with measured field data such as solar irradiance and temperature and load profiles.

4. What is the sizing of PV panels and energy storage systems needed at each home or at distribution level to avoid overloading of distribution transformers, and defer costly infrastructure investments?

The following is a list of the expected information and conclusions to be reported:

1. Mathematical and simulation models to study the impact of ZNE homes and EV charging on the local distribution grids.
2. A generalized linear programming optimization model for optimal energy management of ZNE homes and EV charging that employ PV generation and energy storage.
3. Simulation results and analysis of impacts of ZNE homes and EV charging on distribution grids in two cases: with and without storage systems.

Knowledge, Skills, and Expertise Required for this Project

- Must have completed or currently pursuing one of the following senior power courses: EE380 Fundamentals of Electronic Circuits, EE401 Power Systems, EE402 Wind Power Conversion, EE403 Electric Drives, EE484 Power Electronics.
- Proficiency with MATLAB/Simulink software and SimPowerSystems Toolbox for simulation
- Abilities to research the power system market, electric vehicles, and battery energy storage.

Project Deliverables

- Interim Review Report: 2-page summary and 15-minute PowerPoint presentation on progress and interim results. (Jan. 2019)
- Final report and presentation at the SRP-NAU "Spring Final Meeting.", likely to be held in the Phoenix metro.
- Co-development with SRP of a white paper or a public outreach statement on the impacts of ZNE homes and EV charging on the grid, and possible solutions to mitigate the impacts.

Project Title

Central Inverter for Utility-Scale Photovoltaic Energy Systems

Client

Dr. Venkata Yaramasu

Assistant Professor of Electrical Engineering

School of Informatics, Computing and Cyber Systems (SICCS)

Tel: +1-928-523-6092

E-mail: Venkata.Yaramasu@nau.edu

Project Location

Advanced Motors, Power Electronics, and Renewable Energy (AMPERE) Lab (Room: 090-101)

Project Description

Over the five years between 2010 and 2016, utility-scale solar installations (Fig. 1) have grown at an average rate of 72% each year. For large-scale PV systems, parallel connected two-level voltage source converters and neutral-point clamped converters are used as central inverters. In the current PV market, 19 central inverter models are available from six manufacturers (ABB, Ingeteam, Power Electronics, SMA America, Sungrow, and TMEIC). The largest central inverter in the current PV market has a power rating of 3.36 MW with a DC input voltage of 1500 V.

Since the central inverter is responsible for interfacing a large area of the PV plant, the effect of partial shading becomes more relevant. This issue can be fixed by employing global maximum power point (MPP) searching algorithms, but at an expenses of large power fluctuations in the generated output to the grid during their search. For this reason, industrial large-scale central PV inverters use more conservative maximum power point tracking (MPPT) algorithms and avoid sweeping across the power curve, with the consequent loss in energy yield during partial shading.



Fig. 1 Utility-scale PV farm (Photo of Pinal Central Solar Energy Center in Arizona).

The client finds the problem and opportunity to provide central PV inverter the flexibility to search the global MPP, but without affecting the power output to the grid. The natural solution suggests the use of energy storage, so that the power fluctuations due to global MPP search are compensated by the stored energy. Behind these conclusions lies the motivation of this project, which is to develop the next generation large-scale PV system interfaces with integrated energy storage for improved energy efficiency, reduced manufacturing cost, enhanced system reliability, and grid code compliance with proper control.

A generic block diagram of the proposed modular multilevel converter (MMC)-based central PV inverter configuration is shown in Fig. 2. As mentioned earlier, the central PV inverters are commercially available for 3.5 MW and 1500 V DC input voltage. These ratings imply that the PV systems are low-voltage and high-current systems; hence the low-cost SiC-MOSFET are ideal choice to realize the low-voltage submodules in an MMC. By connecting more number of submodules in series, the voltage across each submodule becomes lower. The large number of submodules result in lower dv/dt , thereby eliminating the grid-side filters. The possible alternatives for submodules are shown in Fig. 2. The first alternative is shown in case if PV energy system does not need to include

energy storage and just feed power extracted from the sun to the grid. The switching device for unidirectional power flow is cheaper than the half-bridge. The second alternative allows the power flow in both directions; hence, energy storage can be included in the DC side of the submodule to suppress fluctuating changes in active power output from the PV plant. Moreover, the energy storage can compensate the partial shading conditions; therefore, global MPP searching algorithms can be employed to extract maximum possible energy from sun and reduce cost of energy.

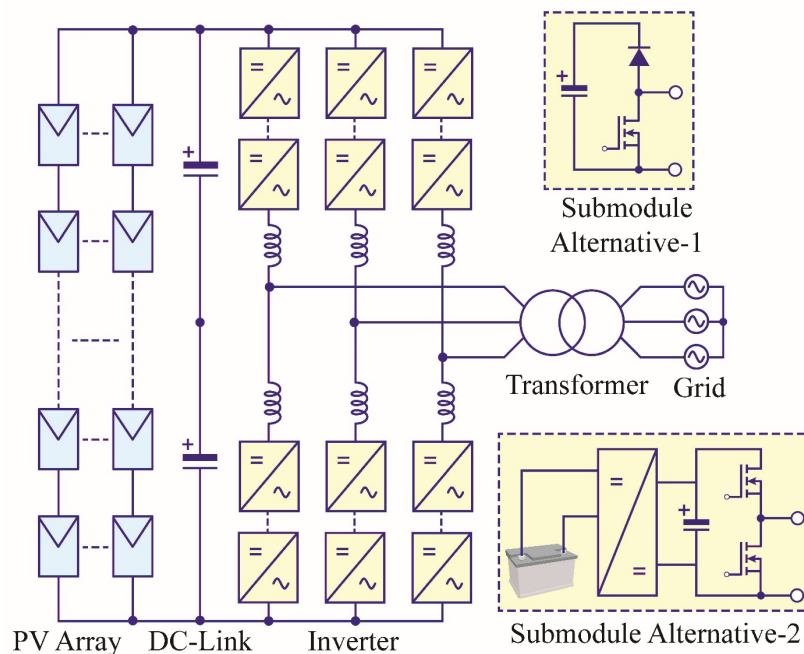


Fig. 2 Central inverter configuration for large-scale PV energy systems.

Knowledge, Skills, and Expertise Required for this Project

- Must have completed or currently pursuing one of the following senior power courses: EE380 Fundamentals of Electronic Circuits, EE401 Power Systems, EE402 Wind Power Conversion, EE403 Electric Drives, EE484 Power Electronics.
- Proficiency with MATLAB/Simulink software and SimPowerSystems Toolbox for simulation
- Proficiency with PCB design softwares such as Altium or OrCAD
- Proficiency with soldering and hardware development
- Ability for dSPACE-based rapid prototyping for digital control

Project Deliverables

An innovative and efficient solution using MMC for the grid-connected large-scale PV system with energy storage will be the product of this project. The interfacing converters will assist in enhancing the stability of the power grid system and thus offers a high reliability. A set of effective control and design methods for the proposed large-scale PV system will be achieved including operation with distorted line voltage (high harmonics and voltage dips compensation). Techniques will be put forth for the compensation of the voltage dip in the grid system and the overall closed-loop stability will be investigated.

The proposed research projects will be carried out in the AMPERE laboratory at the NAU. Since MW-scale prototype cannot be used for testing in laboratories, a reduced scale power converter rated at 5 kW is considered for experimental setup. The whole system will be implemented using the same per unit values as a real power conversion system to retain same operating characteristics for proper validation. The experimental platforms as shown in Fig. 3 will be developed to test PV energy systems. All the equipment and software needed for the experimental works are available, except the power converters and three-phase grid emulator. The MMC prototype and grid emulator will be built in the lab.

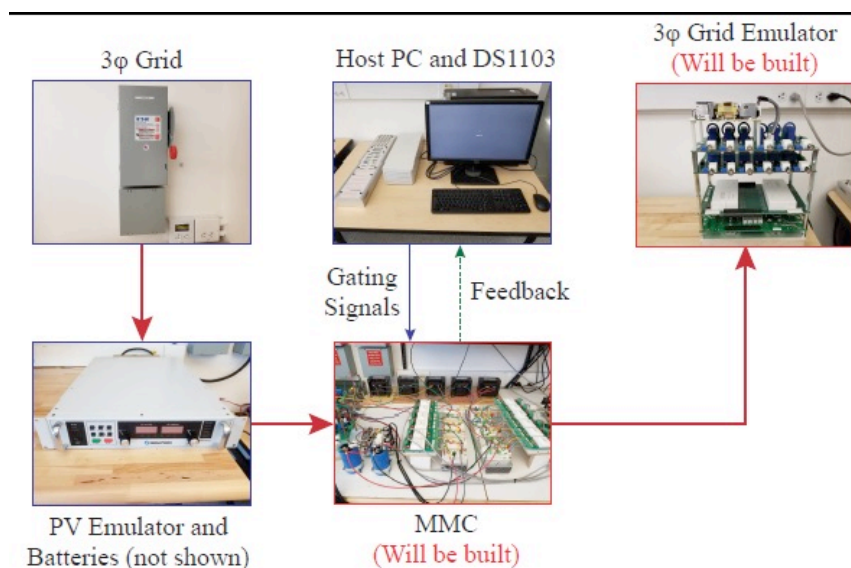


Fig. 3 Anticipated prototype converter for this project.

Project Title

Power Converter for MW-Scale Wind Energy Conversion Energy Systems

Client

Dr. Venkata Yaramasu

Assistant Professor of Electrical Engineering

School of Informatics, Computing and Cyber Systems (SICCS)

Tel: +1-928-523-6092

E-mail: Venkata.Yaramasu@nau.edu

Project Location

Advanced Motors, Power Electronics, and Renewable Energy (AMPERE) Lab (Room: 090-101)

Project Description

Wind energy is one of the fastest growing renewable energy sources and continues to flourish each year in many countries. The size of wind turbines (WTs) has gradually increased over the past 35 years, and has currently reached a massive level of 10 megawatts (MW). The interest of manufacturers in multi-MW turbines has continued to increase, and turbines rated above 2.5 MW represents 18.5% of all 2014 installations. A permanent magnet synchronous generator (PMSG)-based full-variable-speed WT is popularly used in the present wind energy industry. Among the classes of wind generators, PMSG is the most attractive in wind energy conversion systems (WECS) due to high power density and reliability, no need for excitation and gearbox, and lower rotor losses and high efficiency.

The low voltage power converters are efficient and cost effective at power levels lower than 3.0 MW. The medium voltage operation of WECS is the most suitable, reliable, and economical approach for turbine power ratings greater than 3.0 MW. In the present wind energy industry, four MV WTs are operational and several WT manufacturers have announced that their future projects are based on MV technology. The three-level neutral-point-clamped (NPC) converter topology (Fig. 1) is the most attractive choice in the wind energy industry for MV operation.

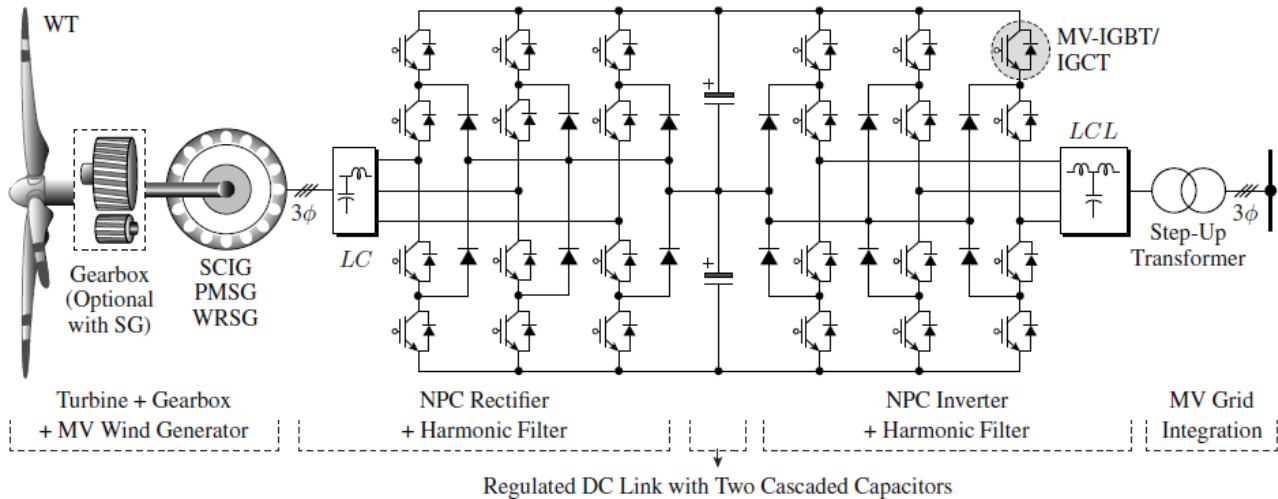


Fig. 1 PMSG WECS with NPC converter.

This project proposes solutions with respect to the power converter topology and digital control schemes for the PMSG WECS. A predictive current control (PCC) scheme will be used to control the power converter.

Knowledge, Skills, and Expertise Required for this Project

- Must have completed or currently pursuing one of the following senior power courses: EE380 Fundamentals of Electronic Circuits, EE401 Power Systems, EE402 Wind Power Conversion, EE403 Electric Drives, EE484 Power Electronics.
- Proficiency with MATLAB/Simulink software and SimPowerSystems Toolbox for simulation
- Proficiency with soldering and hardware development
- Ability for dSPACE-based rapid prototyping for digital control

Project Deliverables

The proposed project is expected to contribute to the current state-of-the-art knowledge and practical development. A prototype converter is expected as an outcome of this project.

The proposed research projects will be carried out in the AMPERE laboratory at the NAU. Since MW-scale prototype cannot be used for testing in laboratories, a reduced scale power converter rated at 5 kW is considered

for experimental setup. The whole system will be implemented using the same per unit values as a real power conversion system to retain same operating characteristics for proper validation. The experimental platforms as shown in Fig. 3 will be developed to test wind energy systems. All the equipment and software needed for the experimental works are available, except the power converter.

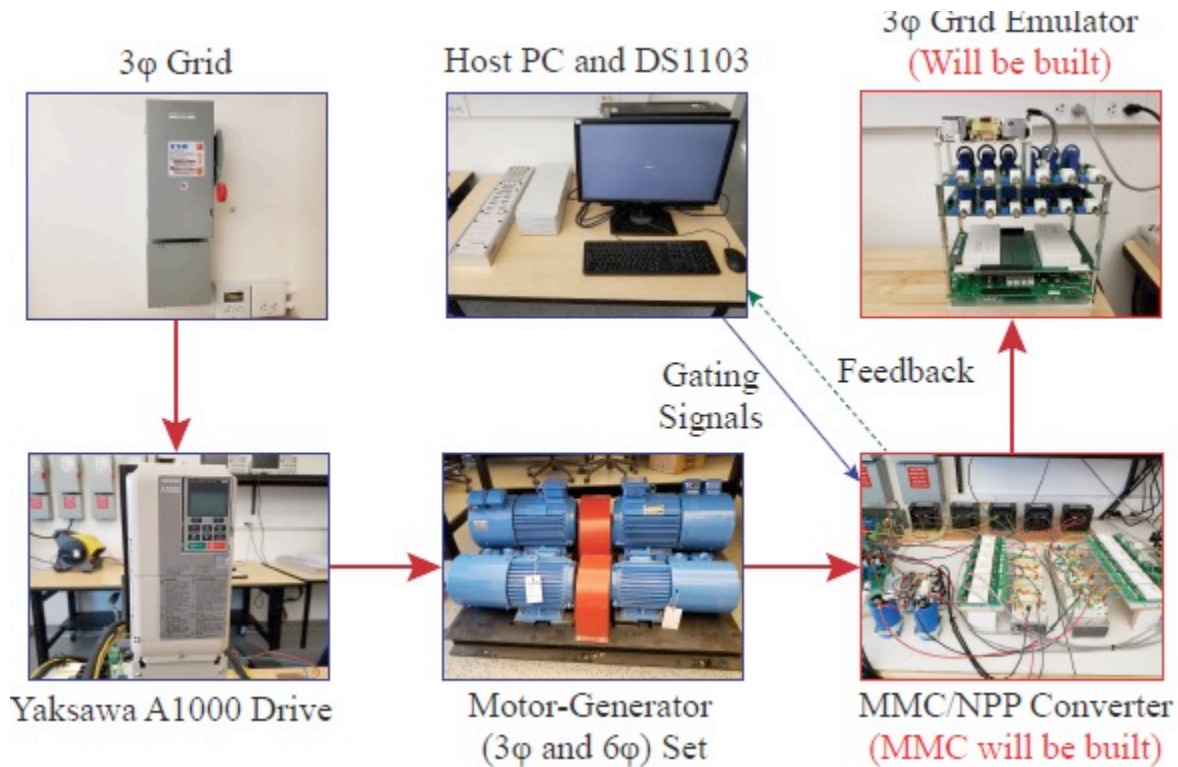


Fig. 3 Anticipated prototype converter for this project.

Remote Cell Wireless Security

EE Capstone Project

Your Client

In the past decade, several companies have begun offering home security systems that differ in concept from the traditional systems offered through subscription service companies. One example if a do-it-yourself install system is that of SimplySafe. While very functional in an urban environment, SimplySafe and the like offer no real functionality in remote areas where Wifi isn't "just available." This project is motivated by exactly that real world scenario.

Dr. Jay Barber owns a remote, off-grid, home in the Snowflake area of Arizona. In his words: I want to install a "security system" on a remote piece of land with no power and poor cell service (except on hills). My motivation for this comes after my in-laws were held at gun point when surprising two thieves on a nearby parcel of land.

I was thinking of setting up a mifi (wireless hot spot) connecting several wireless security devices to the verizon network. Cell service is acceptable (4G) only on two hills on the 40 acre parcel. I was thinking one of two ways: put the mifi on a hill (with solar cell and battery) hoping that the wireless security devices are close enough for communication (??). Or, put a cell "repeater" antenna (on a taller but further hill) (point at the best cell signal then redirect toward the my house where most of the devices, including mifi, will be nearby.) This second option is nice for making calls without hiking to the top a hill, too! I guess this is my preferred option. But, I would leave it to the students to figure out a solution. Again: multiple solar and battery charge controllers are likely necessary.

I want the system to alert me with it detects people (text, email), and I want real time video and (2 way?) audio. I figure that it will often be of no use to get video of hooded thieves; at least I can try to scare them away with audio and contact authorities.


I've looked at proprietary solutions like Netgear's Arlo wireless cameras (etc.) and Netgear's Nighthawk M1 mifi (4G LTE). The mifi is the only one that I could find with an ethernet port, which I thought might be required if the Arlo required a proprietary "base station" hard wired into the mifi ethernet port. But, unfortunately I've read that the port is not really a full-blown ethernet port, but I don't quite understand that. But, fortunately, I've read that Netgear has made the M1 to communicate with the Arlo like directly; no base station required. And, I've read that the mifi will work just fine connected to a charger (battery / cell / charge controller) without the need for the mifi's internal battery. As far as I can tell, the M1 is tied to the ATT network, but I'd like to "break" this and add it as a device on my Verizon account, which I've read is not hard to do. One last thing: I heard that the Arlo devices can work for a few months on a single charge, which seems fine as I usually make it to the land every month or so.

On the other hand, I like the idea of a non-proprietary solution.

At one time, I thought of automatically triggering a siren, but I don't like this because I've had security systems in the past that would have many false detections. Some devices have AI to distinguish between human vs other. A siren would certainly not make my neighbors happy. Of course, if it was made to shut-off after x minutes that might be okay. I like the idea of being able to control the siren remotely. Along these lines, the Arlo devices have 2-way communication, which seems nice, but they have very small speakers, I think, and may not work well. I like the thought of a (very loud) metal metal speaker.

CS486C – Senior Capstone Design in Computer Science

Project Description

Project Title: Implementation of CipherLoc's On-the-Fly Wire Reassignment Technology	
Sponsor Information: 	Dr. Albert H. Carlson, Chief Scientist Research Group CipherLoc Corporation acarlson@cipherloc.net (208) 596-9673

Project Overview:

CipherLoc Corporation, a security provider, is looking to develop a novel way to protect network traffic. We propose to begin using an ethernet network using the CAT5 standards and then change the definition of the wires and their operation while transmission is underway. This requires the use of morphing (so-called “on-the-fly”) changes to the circuitry used for data transmission and reception. In addition, a method to detect passive sniffers, attackers who listen to network traffic without otherwise transmitting or changing that traffic, is also desired. This project aims to create software controlled circuitry that reconfigures the network dynamically at irregular, but frequent intervals.

Details:

Communications between computing machines on hard media typically happens across a statically defined cable or connection. This makes it relatively simple to passively listen and record data exchanged between the two nodes. In fact, many attacks begin with the interception and analysis of data traffic on networks. First the network is analyzed and footprinted, normally to assess the value of the network and to identify the nodes on that network. If the attacker then deems the network to be a valuable target, then attacks begin. Some attacks are merely passive data theft, while others actively insert the attacker into ongoing communications. In some attacks the hacker issues commands and changes the operation of the nodes. In others, data is inserted or removed to change the meaning of the data. Examples of changing, or adding commands, are replay attacks or those that instruct machines to change their behavior from the desired operation, like disconnecting a substation from the electrical power grid. Examples of inserting, or altering communications are sending orders for maintenance with credentials for fictitious persons to allow entry to a facility for other, further attacks. Preventing passive monitoring, or “sniffing,” is a significant step towards eliminating subsequent attacks.

CipherLoc has been developing a way to prevent passive sniffing in a multipronged approach that includes detecting a passive listener and confusing data that is transmitted in order to make it unusable by a sniffer. In the proposed project the team will work on the first stage of the preventive measures: confusing the data and rendering it useless to the attacker(s). This phase of the project is meant to demonstrate that the “on-the-fly” partitioning and operation can be accomplished at speed. Initially this can be discrete hardware, using bi-directional drivers and associated relay/SSR functionality to disconnect the circuitry from the network.

In addition to the hardware, this circuit must be software configurable. The envisioned solution will incorporate the hardware under software control and be tested for the maximum speed that the circuitry can be operated. A “time-to-live” (TTL) function will then be implemented to allow the circuitry to randomize the time that a particular configuration remains valid on the network. Regular interaction with CipherLoc will likely be required with the research team.

It is envisioned that all of the eight (8) wires in a Category 5 (Cat5) cable be enabled for both transmission and receiving. Although both elements are present on a single network wire, only one will be enabled for use at any time. This can be done with a bi-directional driver. The change-over must be done when the definition of the line changes in less than a single bit transmission time.

Further, in order to detect a passive sniffer the transceiver used on the wire must be automatically disconnected from the network and a unit step function is applied to each of the wires in the network. The waveform resulting from applying the step function is monitored and the time constant associated with the network media is then calculated. The time constant, τ , is a function of the R, L, and C of the media and is characteristic of the network media. If a sniffer is present, a change to the τ value will result. This will allow for detection of the sniffer. All nodes on a network must simultaneously disconnect from the network during this test. Disconnection occurs at random intervals, known as the "TTL," that are randomly selected and shared by all of the nodes on the network.

To further complicate matters, those wires not used in passing valid data will have "fake" messages transmitted on the wires to simulate real traffic so that the attacker has to decide which data is correct. Data can be as simple as other real messages that are copied from a network and then placed on the unused wires. Such messages are known as "cryptographic nulls," or "crypto-nulls." These messages are ignored by the receiver node and are only transmitted to confuse an attacker. Since all wires are used, this requires the attacker to sort through a possible $\binom{8}{4} 4! = 1620$ possible pairings for the wires.

Some features expected for this produce are:

- Externally controlled bi-directional/tri-state communications circuitry on a per wire basis
- On-the-fly reconfiguration of data receiver/drivers
- TTL determination and scheduling for reprogramming the configuration of the receivers/drivers
- Automated partitioning of the receiver/driver circuitry
- Automated disconnect from the network for individual lines connecting to the receivers/drivers with a 1500V isolation from wire to wire
- Basic cryptographic nulls operation on the drivers

This product has widespread application and impact in network security defense products. It will allow users to secure their communications by altering the mix of data that is transported on the affected network. Attackers will have to be able to record and sort messages without knowing where various submessage streams begin and/or end. It has the potential of vastly upgrading methods of physically safeguarding personal privacy. The product could reduce data theft significantly and protect users from loss of funds or vital information.

The minimum requirements for this project are:

1. Bidirectional capability for all wires on the network
2. Automated selection of wire definition
3. Automatic redefinition of wires
4. Selection of the TTL
5. Disconnecting the wires according to the appropriate TTL
6. Creation of a step function to apply to the network
7. Monitoring the value for τ on the wires of the network

Knowledge, skills, and expertise required for this project:

- Analog design
- Embedded systems, both hardware and software
- C++ programming
- Cryptonull generation
- Digital communications protocols

Equipment Requirements:

- There should be no equipment or software required other than a development platform and software/tools freely available online.

Software and other Deliverables:

- Code used to
 - Generate the cryptonulls
 - Implement the controllable drivers
 - Reprovision the hardware receivers/drivers on-the-fly
 - Determine and implement TTL values
 - Determine times and intervals of disconnecting the receivers/drivers from the network
 - Test the maximum speed of the unit
- Bill of materials for the design
- Schematic of the receiver/driver and disconnect unit
- Test vectors in software form for the design
- A strong as-built report detailing the design and implementation of the product in a complete, clear and professional manner. This document should provide a strong basis for future development of the product.
- Complete professionally-documented codebase, delivered both as a repository in GitHub and as a physical archive on a USB drive.

Anticipated major phases for the project are as follows:

- Sept to Dec. EE students develop the receiver/driver implementation; CS student study the embedded and switching technology
- Jan to March: Implementation & testing
- April: documentation, and oral presentation

The project manager for the project will meet weekly with team members to monitor progress and to provide guidance for the project. Parts will be provided by the company for development and for prototyping.

ANEUVAS TECHNOLOGIES, INC.

2225 N Gemini Rd. Ste. E6
Flagstaff, AZ 86001
928-814-4085
aneuvas@att.net



Aneuvus Technologies, Inc 3-Way Mixing Syringe Pump
August 2018

Title: 3-Way Mixing Syringe Pump**Information on Project Sponsor:**

Aneuvus Technologies, Inc (ATI) is a small start-up company located in Flagstaff, AZ. ATI's mission is to improve human healthcare by developing novel microcatheter-based medical devices for minimally invasive delivery to the blood vessels in the brain, for the treatment of aneurysms and other vascular defects.

At Aneuvus Technologies, Inc, current product focus is PPODA-QT - a liquid embolic for treating aneurysms by completely filling the aneurysm sac, completely removing the aneurysm from vessel flow, and completely healing the vessel at the aneurysm neck. Currently approved devices exhibit incomplete results in these areas.

Scope of Work:

The scope of this project is to build upon or redesign an existing prototype - and test a syringe pump mixing system for mixing 3 liquid components housed in syringes and connected by a 3-way adapter. The system must be programmable to mix specific syringes at specific flow rates for a set time (two syringes mixing at a time). The system must be able to perform the programmed mixing protocol in a consistent and reproducible manner.

Overall Requirements:

1. Develop a system that will mix 3 liquid components together within syringes
 - Level of mixing will be determined using a rheometer (access through the NAU BDL)
2. Duration and rate of mixing must be programmable and adjustable

Desired Engineering Major: Mechanical and Electrical

Budget:

\$1,500¹ to cover the cost of:

- Documentation (reports, presentation boards, etc.)
- Materials for testing and prototyping
- Construction of working model

Deliverables:

Literature review, project proposal, final report, engineering analysis, prototype system with resulting data, cost estimate for duplication, bill of materials, detailed procedure for repeatable manufacturing, and all expenses (notify client of intended purchases, or submit receipts for reimbursement within 1-week of purchase).

¹ Other resources may be provided as needed/justified.

CS486C – Senior Capstone Design in Computer Science

Project Description

Project Title: Temperature and Flow Control for an Integrated Aquarium	
Sponsor Information: Six Guys Research Group	Dr. Albert H. Carlson Lead Researcher Six Guys Research Group Ltzap1@gmail.com (208) 596-9673

Project Overview:

Every year the tropical fish industry imports more than 6 million tropical fish into the US. This is in addition to fish imported to a very large European and Asian market. While this number represents a small portion of the fish population for any single year, repeated removal of these fish can damage the wild stocks and can potentially damage the ability of the populations to naturally renew themselves. Many fish can be bred in captivity, but there are a large number of fish that, at this time, cannot be domestically bred. Six Guys Research Group is attempting to solve this problem by simulating the environment of the fish to allow for domestic breeding of various tropical fish. Such an effort will require automated control over the environment to simulate the weather, visual, and water chemical clues that are often used by fish to cause them to breed.

Details:

Conservation and the diversity of fish species is of great concern given the intrusion of man into previously wild habitats. In addition to habitat loss, man has affected wild populations of fish via climate disturbance and by removing portions of a population from their original range. If the fish become popular in the aquarium trade after being identified, significant numbers of the population may be removed. Such capture can result in the loss of a critical mass of that population and may cause the population to fail. However, captive populations can also serve to preserve these populations in case of natural disaster or loss of sufficient populations.

Preserving captive populations requires that they reproduce in captivity. Some fish will reproduce under almost **any** conditions, but many fish require environmental clues to trigger reproduction. These clues include the variation of light on a daily basis, weather, variations in water levels, food availability/menu, as well as changes in water chemistry. By matching to conditions to those where the fish is endemic, the probability of triggering reproduction is greatly enhanced.

Most modern aquariums maintain only a single set of conditions known to allow the fish to live for extended periods of time. Matching the weather/environmental conditions at the source for the fish would require a human to constantly adjust conditions in an aquarium. Therefore, an integrated and automated aquarium solution is required. Six Guys Research Group was formed to attempt to solve this problem. At this time, Six Guys is producing a light system that simulates the lighting cycles in the wild environment. However, the talent pool for the group is too small to produce the hardware and associated software required for complete integration.

The next required steps for a basic integrated set up are the controls for the water temperature and water flow control. Water flow control is used to filter the water, make water changes, and to vary water chemistry. A simplified system diagram for the unit is shown in Figure 1. Water is recycled through a set of pipes where it can be heated, filtered, and even removed/added as needed. As water circulates it passes by an aquarium heater and the water is then returned to the aquarium. There is a reservoir of water (the “tank”) where water is aged prior to water changes. Using the two valves shown, water can either be directed to a drain or returned to the tank, and drawn from the tank, as needed. With proper controls over the water, lights, and heating, most important functions in the aquarium can be controlled through and integrated controller. The control chosen for this purpose is the Arduino Mega2500.

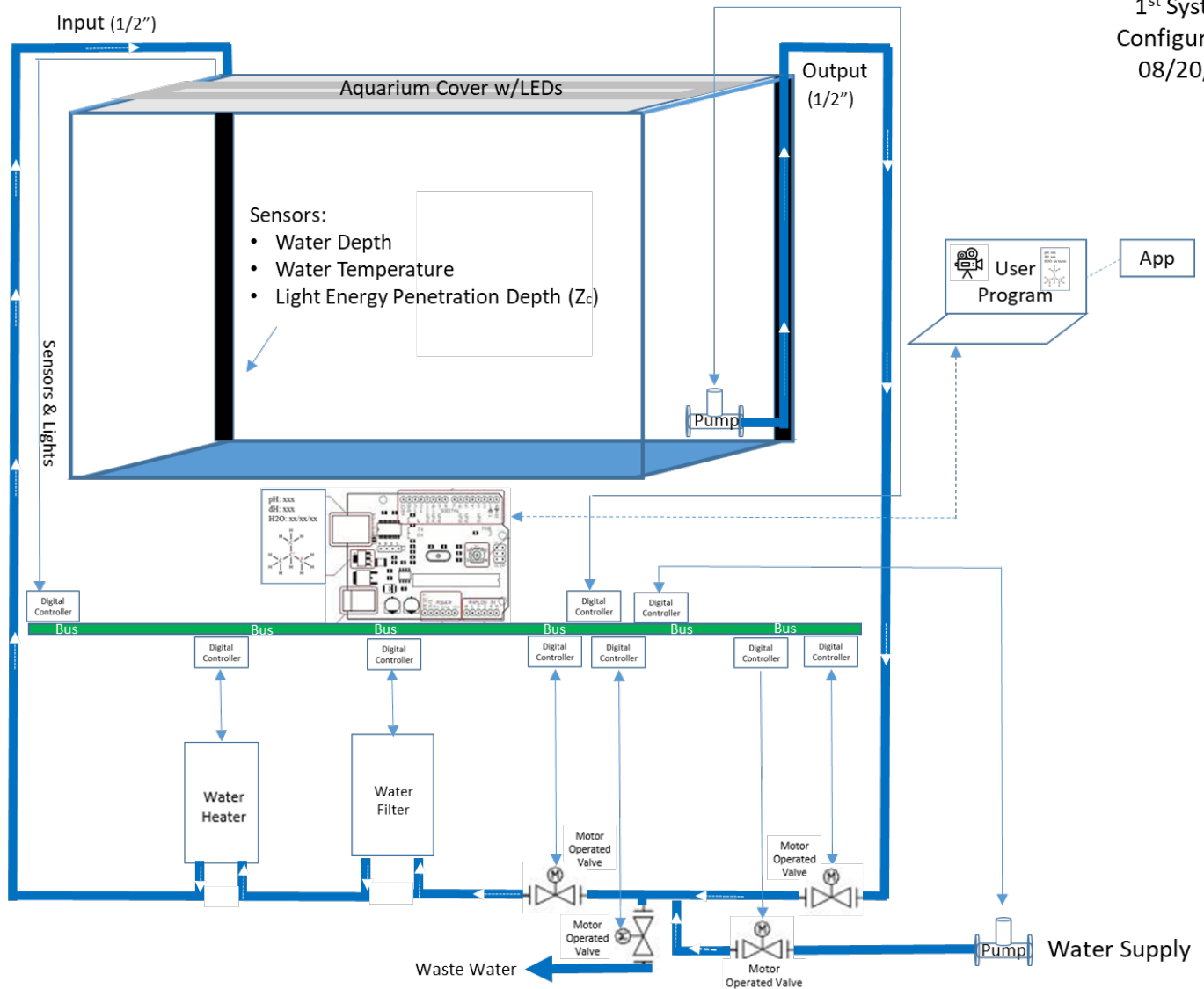


Figure 1 System Diagram

The solution envisioned to accomplish this task requires the following:

1. Create a database to hold the required data to run the unit for a 365/6 day period (and account for leap year)
2. Provide an interface to a computer or a FLASH drive to load data into the database
3. Follow data in the database to alter the water temperature
4. Control the water valves and pump to provide for continuous water flow
5. Regularly measure the water flow and depth
6. On a daily basis adjust the water depth to levels stored in the database
7. Once a week provide a water change 30% of the water in the aquarium with water from the tank in such a way as to not radically change the water levels over a short period of time and disturb the fish, dumping excess water to a drain
8. (If time allows) Include a function to do daily water changes and make it optional to the user
9. (If time allows) Allow for remote scheduling of water change times and dates from user input

10. (If time allows) Create a mechanism to control more than just two valves and map the valves to create the ability to network two, or more, aquariums for water changes
11. (If time allows) Connect the controller via wireless to the network and accept option changes and data updates via wireless

This phase of the project is meant to create the base system required for proof of the environmental clues concept for tropical fish. Specifically, steps 1 – 7 are required. Steps 8 -11 can be attempted and are desired if there is enough time to work on those steps. However, they are strictly optional. Six Guys will provide access to Subject Matter Experts for the design.

Knowledge, skills, and expertise required for this project:

- Analog design
- Embedded systems, both hardware and software
- C++ programming

Equipment Requirements:

- There should be no equipment or software required other than a development platform and software/tools freely available online.
- Six Guys will provide the necessary parts for test and construction, to include
 - An Arduino Mega2500
 - Aquarium heater
 - Tubing
 - Valves
 - Pump
 - Aquarium/Tank

Software and other Deliverables:

- Code used to
 - Control the heater
 - Monitor the temperature in the water system
 - Control the valves
 - Handle the routing of the water, considering the valves
 - Read, configure, and load the database
 - Schedule and complete water changes
 - Basic GUI for users to set up the timing and control of the circuitry
 - Read, set up, and keep the internal clock
 - Any optional coding there is time to complete
- Bill of materials for the design
- Schematic of the pulse unit and disconnect unit to the network
- Test vectors in software form for the design
- A strong as-built report detailing the design and implementation of the product in a complete, clear and professional manner. This document should provide a strong basis for future development of the product.
- Complete professionally-documented codebase, delivered both as a repository in GitHub and as a physical archive on a USB drive.

Anticipated major phases for the project are as follows:


- Sept to Dec. EE students develop the receiver/driver implementation; CS student study the embedded and switching technology

- Jan to March: Implementation & testing
- April: documentation, and oral presentation

The project manager for the project will meet weekly with team members to monitor progress and to provide guidance for the project. Parts will be provided by the company for development and for prototyping.

CS486C – Senior Capstone Design in Computer Science

Project Description

Project Title: Implementation of CipherLoc's Passive Sniffer Detector	
Sponsor Information: 	Dr. Albert H. Carlson, Chief Scientist Research Group CipherLoc Corporation acarlson@cipherloc.net (208) 596-9673

Project Overview:

CipherLoc Corporation, a security provider, is looking to develop a novel way to protect networks from attackers that passively connect to a network and monitor traffic on that network. We propose to synchronize nodes on the network, create a schedule for applying a signal to the network and observe the response. Based on a signature read from the network media and properly connected nodes an applied signal placed on a wire results in a waveform that can be read to determine if the network has been invaded by one, or more, unauthorized node. This node is assumed to be an intruder.

Details:

Communications between computing machines on hard media typically happens across a statically defined cable or connection. This makes it relatively simple to passively listen and record data exchanged between the two nodes. In fact, many attacks begin with the interception and analysis of data traffic on networks. First the network is analyzed and footprinted, normally to assess the value of the network and to identify the nodes on that network. If the attacker then deems the network to be a valuable target, then attacks begin. Some attacks are merely passive data theft, while others actively insert the attacker into ongoing communications. In some attacks the hacker issues commands and changes the operation of the nodes. Examples of inserting, or altering communications are sending orders for maintenance with credentials for fictitious persons to allow entry to a facility for other, further attacks. Preventing passive monitoring, or “sniffing,” is a significant step towards eliminating subsequent attacks.

CipherLoc has been developing a way to prevent passive sniffing in a multipronged approach that includes detecting a passive listener and confusing data that is transmitted in order to make it unusable by a sniffer. In the proposed project the team will work on the second stage of the preventive measures: identifying passive sniffing nodes attached to the network. This method is based on the electrical characterization of the network using Thevenin and Norton equivalents that describe the network under all rest and operational conditions.

Every network can be described by the resistance, inductance, and capacitance associated with the media and attached nodes, as shown in Figure 1. As a result, the electrical response to an applied unit step function is an exponential rise and fall with a time constant of τ . From physics we know that the time of a response of an RLC type circuit, from 10% to 90% of the amplitude of the applied signal is 2.2τ . Further, we also know that

$$\tau = \frac{R}{\sqrt{LC}}$$

Connecting any circuit to the network will change the time constant from $\tau \rightarrow \tau'$, where

$$\tau' = \frac{R'}{\sqrt{L'C'}}$$

because of changes to the values of R, L, and/or C by adding additional components to the network via new network interfaces.

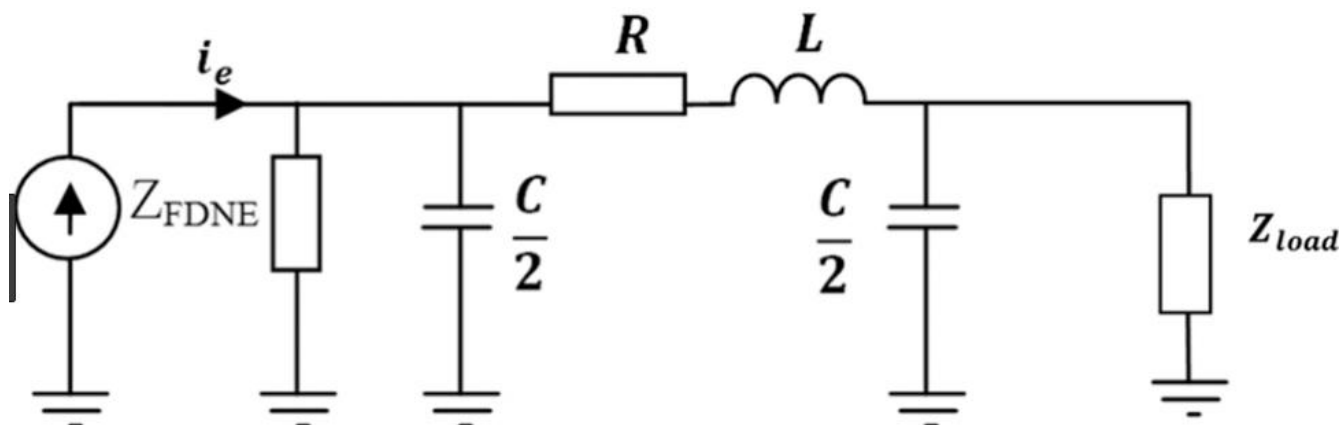


Figure 1 Network Equivalent (from: <https://www.degruyter.com/view/i/ijeeps.ahead-of-print/ijeeps-2017-0104/ijeeps-2017-0104.xml>)

If a short signal is applied and the response to that signal is monitored, the value of the measured τ' can be compared against the signature τ originally measured for the network. Differences between τ and τ' indicate the presence of an unauthorized addition to the network.

The solution envisioned requires the following:

1. Characterizing the network by applying an input signal to the network and recording the results of the response to the signal. This signal should be as large as possible to make the measurement as easy and accurate as possible. CAT5 cable has a dielectric breakdown rated at 1500V. Use of this high a voltage is desired for use and will require a voltage generator.
2. Voltage is applied to the network.
3. Network response is measured and compared to the signature.
4. Response is taken to the results of the measurement.
5. A new Time to Live (interval to next check) is then made and implemented. TTLs are calculated using an RNG which must be chosen and implemented.

This phase of the project is meant to demonstrate that it is possible to detect added nodes that are not synchronized to the operation of the network. The envisioned solution is one which accomplishes steps 1 – 4 above. A desired, but not required goal, is to interface with a second team at NAU to integrate the hardware with an on-the-fly reconfiguration of network functionality.

Knowledge, skills, and expertise required for this project:

- Analog design
- Embedded systems, both hardware and software
- C++ programming
- Digital communications protocols

Equipment Requirements:

- There should be no equipment or software required other than a development platform and software/tools freely available online.

Software and other Deliverables:

- Code used to

- Control the removal of the node and insertion of voltage source
- Calculate the TTL for the time between applications of the pulse
- Create the pulse source
- Training the circuit for developing the network signature
- Compare readings for the network and compare it to the signature
- Test the sensitivity of the method to additional nodes on the network
- Bill of materials for the design
- Schematic of the pulse unit and disconnect unit to the network
- Test vectors in software form for the design
- A strong as-built report detailing the design and implementation of the product in a complete, clear and professional manner. This document should provide a strong basis for future development of the product.
- Complete professionally-documented codebase, delivered both as a repository in GitHub and as a physical archive on a USB drive.

Anticipated major phases for the project are as follows:

- Sept to Dec. EE students develop the receiver/driver implementation; CS student study the embedded and switching technology
- Jan to March: Implementation & testing
- April: documentation, and oral presentation

The project manager for the project will meet weekly with team members to monitor progress and to provide guidance for the project. Parts will be provided by the company for development and for prototyping.

Modular Wireless Testbed

EE Capstone Project

Your Client

Dr. Morgan Vigil-Hayes is researcher/professor in SICCS. She is interested in developing an easy-to-use, modular wireless testbed that allows me and my students to run high-fidelity wireless experiments with heterogeneous network technologies (e.g., various variants of 802.11, Bluetooth, Zigbee, LoRa) in a number of environments and scenarios.

There is a need for unifying and modular control that can make heterogeneous network set-up fairly plug-and-play. Right now, she needs to have students set up individual antennas and network interface cards for every single network interface that they are running experiments on. There is not an existing way to easily configure a heterogeneously networked node.

From this, she needs a mobile-friendly, software-configurable widget (such as a Raspberry Pi + easy for the non-EE breadboard + software + off-grid power) that enables or disables various network interfaces and also runs a light weight version of Linux that allows her and her students to run networked code across the interfaces.

One of the major challenges with wireless networking systems is that it can be difficult to accurately evaluate their performance in a simulated environment, since the data communication layer can be significantly impacted by line-of-sight obstacles, interference, and path fading. Her lab seeks to deliver applications and architectures over heterogeneous wireless networks and in order to accurately evaluate usability and performance, we need an on-the-fly configurable testbed that can mobilize into various configurations in the physical world to evaluate real-world deployment scenarios.

In addition, it is exceptionally difficult to demonstrate some of the challenges of wireless networking or to measure the impact of wireless on various Layer 3-5 protocols or to evaluate the difference between Layer 2 protocols in a computer networks course without extensive equipment setup. It would be really great to have something that could be configured easily from a command line (i.e., my widget nodes could be controlled in the cloud)!

Prototype Milestones

This project will closely adhere to the deadlines set in class.

Project Features

1. The product must enable software configuration of network interfaces.
2. ... must support at least 4 networked technologies simultaneously: FM RBDS receiver, WiFi mesh, WiFi access point, LoRa.
3. ... must support modularity such that I could easily add a new networked technology to the node.
4. ... must be small enough to be mobile (i.e., can fit in a backpack).
5. ... must enable topographic configuration such that units can network together to form a single local network (i.e., one giant offline mesh), or have some meshed units operate as gateway nodes, or have specific nodes coordinated to talk to each other and not other nodes.
6. ... should some of the specific aspects associated with the antennas (i.e., specific WiFi channel) would be configurable with software.

7. ... ideally there would be an API that enables the support of adding new configurable antennas.

Project Success

The end product will be able to transmit and receive wireless data transmissions from multiple network technologies simultaneously as part of a mobile lab testbed environment. All nodes should be simultaneously configurable using a simple software user interface (command line is fine) with a configuration file format that can run from an office bound desktop computer.

Satisfaction Standards

Exemplary - The user interface is easy to use and provides clear configuration options. The final product is so stellar that Dr. Vigil-Hayes is able to being using the product for her class next year.

Good - The final product is functional and complete, with a user interface that is pretty easy to use. The product is ready for “prime time,” but still needs some work to make it ideal.

Fair - The basics are there, with a user interface that is usable, but this isn’t the kind of product anyone actually wants to use.

Poor - The final product is a box of parts, some of which might work individually, but nothing works in unison.

Special Team Skills

Students on this project should have taken some Computer Science or Computer Engineering courses beyond that which is required for Electrical Engineering. A background knowledge in embedded programming will be a real plus here.

Specialty Equipment

This project will require special antennas (LoRa, FM RBDS receiver, WiFi mesh, WiFi AP), which be provided by Dr. Vigil-Hayes.

Electric Drives Instrumentation Platform

EE Capstone Project

Your Client

Dr. Yaramasu currently teaches the Electric Drives class at NAU using Matlab Simulink and a software/hardware solution from dSpace GmbH. This solution is quite expensive with dSpace hardware costing \$4000 per unit and software upgrades costing \$300 per unit. The problem is that upgrading or adding hardware and software with this solution is expensive. It's also extremely difficult for students to replicate this solution at home.

The dSpace software has a tried and true solution and NAU has well developed labs built around this solution. Although cheaper alternatives built around cheaper hardware like the Arduino may be possible, we don't understand the implementation details or impact this might have as an alternative. We would like for a Capstone team to build an Arduino based solution that can be used to implement the labs and coursework for Dr. Yaramasu's Electric Drives class.

This work could be used as a prototype for using Arduinos in the Electric Drives class at NAU or any other university. This work could make Electrical Engineering curriculum more accessible to universities that don't have expensive hardware to support an electric drives class. One might be able to envision how this could also be a platform small startups or hobbyists could use to develop a hardware design. As such, documentation and development of the materials to share this design worldwide is of great value.

Prototype Milestones

By December of this year: A feasibility demonstration that shows an Arduino based solution controlling an electric drive in the kind of scenario you might find in one of the Electric Drives labs.

By late May of 2019 (UGrads): All of Dr. Yaramasu's labs will have implemented using a robust Arduino based control solution. An analysis of the old solution compared with the new solution (e.g., advantages and disadvantages).

Project Features

1. The solution must support Matlab/Simulink workflow.
2. ... must make the same kinds of measurements and control as current solution.
3. ... must be robust (i.e., not easy for students to destroy).
4. ... must support same learning outcomes for students as current solution.
5. ... should supports similar lab design and setup as current solution.
6. ... should be low-cost.
7. ... ideally is easy/cheap to replicate.
8. ... ideally is ready for sharing world wide.

Project Success

This project would be a success if this solution was ready and deployed in the Electric Drives class.

Satisfaction Standards

Exemplary - A robust platform is developed and all existing labs have been re-implemented in such a way that students using these labs have a comparable experience, when compared with the existing dSpace solution.

Good - Most labs are re-implemented with an experience that is notably different, but acceptable in that many of the same teaching objectives can be achieved.

Fair - Less than half of the labs are able to use a working, but not particularly practical solution.

Poor - A working alternative is not developed and/or labs are not developed that illustrate the solution. Some parts may function independently, but not in a manner than could be used by students taking the lab class.

Special Team Skills

Students on this team should have prior experience in Dr. Yaramasu's Electric Drives class, prior experience working with the Arduino platform, and prior experience working with Matlab/Simulink. Critical to designing and developing replacement lab material, the students on this team should also have excellent oral and writing skills.

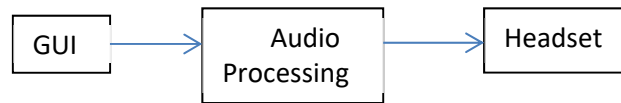
Specialty Equipment

The dSpace Electric Drives hardware will be needed as a reference solution, and is available in 69-234.

“Virtual” 3D Audio

Overview

Our ears and brain work together to interpret the sounds picked up from each ear and determine, with incredible accuracy, the sound’s location. Design a system that will mimic this 3D audio in a headset.



System Block Diagram

Details

- System shall function in real time
- The GUI is the interface to the system and allows the user to select the sound’s location relative to the headset in a 3D environment.
- The audio headset interface shall use a standard audio jack from a PC or stereo
- The audio processing may be implemented via an algorithm within a laptop or through a student designed hardware/firmware solution (ie, DSP, FPGA, etc)
- System shall be capable of driving a stereo headset
- The audio processing should create the perception of the sound’s location (as specified by the GUI) using phased audio, not just volume changes.

COBHAM PRIVATE

THIS DOCUMENT CONTAINS PROPRIETARY INFORMATION.

NEITHER RECEIPT NOR POSSESSION OF THIS DOCUMENT CONFERS ANY RIGHT TO REPRODUCE, USE OR DISCLOSE, IN WHOLE OR IN PART, ANY INFORMATION CONTAINED IN THIS DOCUMENT WITHOUT WRITTEN AUTHORIZATION FROM WULFSBERG ELECTRONICS.

Audio Noise Cancellation for Periodic Interference

Overview

This effort will develop an audio noise cancellation system suitable for state of the art communications equipment. The resultant system will provide superior audio quality for use in an environment with high levels of ambient background rotor noise.

Background

Active noise cancellation is available using secondary microphones, but current helicopter microphones provide a single source of audio. The ambient rotor noise is impressed upon that single channel of audio signal. Clever signal detection and processing may allow for “subtraction” of a periodic signal produced by a rotor, allowing for improved intelligibility of the spoken voice.

Details

We are looking for a DSP only solution to improve the intelligibility of the spoken voice when helicopter rotor noise has been added.

A detection/filter needs to be developed to extract the periodic signal with a low/fixed frequency range (the rotor). That extracted signal need to be subtracted from the audio channel.

Correlation and time averaging with decay will be needed to construct the interfering signal, realizing that the rotor speed can slowly vary, and that this will be an imperfect signal.

The end goal is not perfect reproduction of the speech minus the rotor, only substantial improvement in intelligibility.

Sample audio files will be provided.

THIS DOCUMENT CONTAINS PROPRIETARY INFORMATION.

NEITHER RECEIPT NOR POSSESSION OF THIS DOCUMENT CONFERS ANY RIGHT TO REPRODUCE, USE OR DISCLOSE, IN WHOLE OR IN PART, ANY INFORMATION CONTAINED IN THIS DOCUMENT WITHOUT WRITTEN AUTHORIZATION FROM WULFSBERG ELECTRONICS.

Cave Climate Monitor

EE Capstone Project

Your Client

The U.S. Geological Survey - Astrogeology Branch has great interest in monitoring cave climates. While terrestrial caves are of interest, the greater interest is on extra-terrestrial caves. Current cave climate monitoring is done through direct observation by spelunkers. While this works on Earth (terrestrial applications), it's not yet feasible for extra-terrestrial caves. This method is also very limited in the amount of data that can be recovered on the climate of any given cave.

As of yet, there is no existing technology that allows researchers to easily deploy climate stations throughout a cave and to record temporary (time) rich measures of temperature, humidity, pressure, or wind patterns. This project will address this technology gap by developing the hardware and software to relay climate readings through a network from the depths of a cave to the surface, where another technology can be used to report measures to the researchers. The goal is to have sensor- network cubes that can be dropped throughout a cave and seamlessly connect to each other so that the climate data collected can be transmitted (relayed) through the cave to the entrance where a modem could fire the data back to home base via cellular or satellite phone.

Dr. Timothy Titus, your client, leads the group that discovered caves on Mars.

Prototype Milestones

By the end of the fall semester, the team should have prototyped climate sensors, and have started the network design. Other prototypes should include water proofing and energy storage. By late February, the team should be ready to test a development version of the system in the Flagstaff Lava River Cave. By mid April, this system should be ready for deployment by involved space scientists in other caves around the state.

Project Features

1. The solution must be able to record climate data (temperature, humidity, pressure) at every, or nearly every station (device in the cave).
2. ... must be able to relay measures from one station to another, in order to retrieve data from the most distal device.
3. ... must be able to interface with either a satellite phone, cellular phone, or APRS modem to relay measures to a base station (server, email, etc).
4. ... must be water and humidity resistant.
5. ... should be camouflaged to prevent theft in popular caves.
6. ... should be small enough such that two spelunkers are able to deploy up to ten stations alone (at least five should fit in a small backpack).
7. ... should be able to collect and transmit for at least one month without a battery replacement or charge.
8. ... should be configurable by the research team, in order to change aspects of sample rate or sensor type, along with any factors that may impact battery life/use.
9. ... should be able to record climate data (wind) at several stations (device in the cave).
10. ... ideally can support wireless configuration changes.
11. ... ideally is designed and documented in a manner that allows the research team to share plans and design files with other research teams, adhering to a free source model.

Project Success

A successful project will result in a collection of as-is usable devices that the research team can deploy in caves around northern Arizona without the need for an engineer on staff to maintain them. An exceptionally successful project will result in all the documentation and design plans needed to share your efforts with researchers worldwide.

Satisfaction Standards

Exemplary - The final product is so good that the client is able to start using it in April/May with the expectation of using it for the next two years without major servicing in the cave's extreme environment (humidity, direct water exposure, temperatures below freezing).

Good - The final product works as expected, but does require significant additional training of the end user or regular servicing to keep the products functional.

Fair - The system functions, somewhat, but is not to a stage that it can actually be deployed for real use. This system is more of a "proof-of-concept" than a usable product.

Poor - The system really doesn't work, or maybe just parts of it work, but calling it a "proof-of-concept" would be an overstatement. The finished product is something closer to what is expected during the prototype development phase.

Special Team Skills

While this project may not require any special skills beyond your undergraduate education, the team should be prepared to test the system that the team develops in a local cave such as the Flagstaff Lava River Cave.

Specialty Equipment

A satellite/cellular/radio modem will be required. The team will be encouraged to consider how to develop technology that can interface with any of these, as this may prove to be a constraint for the team.

Flagstaff Lava River Cave FS Website:

<https://www.fs.usda.gov/recarea/coconino/recarea/?recid=55122&actid=102>

Summary

The goal of this Capstone Project is to perform a series of engineering tasks which are required for launching a new product. The students will be operating as Product Development Engineers helping to define device characteristics and assisting the company to identify the optimal device structure through electrical testing and data analysis.

Background

A newly identified operating mode of the a Physical Unclonable Function (PUF) has been observed within a Resistive Ram (ReRAM) structure. Due to the unique characteristics of this unique element, the PUF structure and method of operation offer a highly secure element for providing hardware security. A single element provides a random tri-state value (“1”, “X” or “0”). Another unique feature is the PUF provides a tamper-proof element which offers a high-level of security unseen by prior PUF structures such as SRAM or ring oscillators. This new PUF device has the potential to form encryption methods which can be unbreakable even with quantum computing. Another attractive feature for this element is its fabrication process is compatible with standard semiconductor processing, permitting hardware security directly within a semiconductor IC.

Program Description

PUF production will be performed by BRIDG. BRIDG, located in NeoCity Florida which is adjacent to Orlando, operates a new and versatile 200mm microelectronics wafer fabrication and R&D facility for advanced sensors, semiconductors, III-V materials and integration technologies. With nearly 60,000 square feet of laboratory/manufacturing space inside a 109,000 square foot building which includes two cleanrooms. The PUF development will be one of the first devices manufactured on the BRIDG production line.

The challenge with a new technology such as this is understanding the affects of the processing, materials and features on the device performance. BRIDG will be producing 200mm wafers with various device features and intended process changes to understand the critical parameters which affect the PUF device. The PUF elements will exist in crossbar arrays with probe pads for external probing. For example, Figure 1 shows multiple arrays of PUF elements which will be produced on a wafer. Each lettered array contains PUF elements of one fixed dimension, but each array is different. One part of the engineering effort is to identify how these variations behave when tested. Anomalies or variations will be further investigated by BRIDG using destructive testing such as cross-sectioning and SEM/EDX analysis.

To gain further knowledge about the affects of the fabrication process, multiple lots of wafers will be produced using different fabrication techniques. Data collected from testing and analyzing the wafers will assisting with refining the processes towards a manufacturing standard. The PUF is intended to be a random element and have a low probability of predicting its state. One of the team’s goals will be to determine if any predictability is possible from any of the various methods of fabrication.

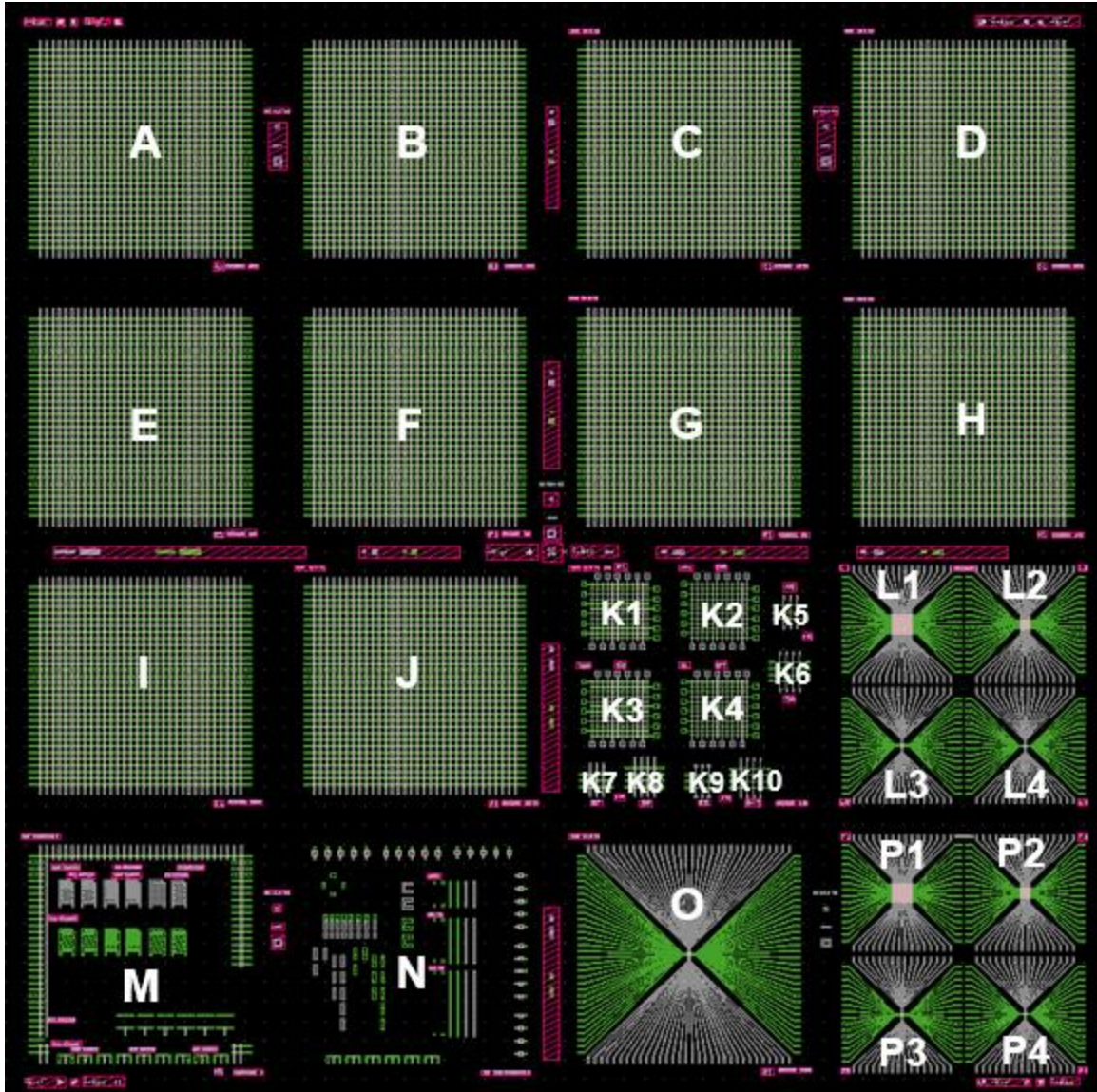


Figure 1. Representative layout of crossbar arrays containing various dimensioned PUF elements.

As the product development team, the team will be provided with information about the PUF elements being supplied, such as dimensions, pitch or process method. The team will be developing and performing electrical tests for evaluating the devices. In conjunction with BRIDG engineers the team will determine the various tests and procedures and act on the plans which have been created. Test conditions which will be important are drive currents, pulse widths, duty cycles and temperature. The team will be responsible for organizing the test equipment, writing any test code, capturing and analyzing the data.

Milestones

During the project, the team will be expected to have a conference call with the BRIG engineering team every other week or more as needed. The meetings will used to review results, project status, address

any problems or issues the team is encountering and present possible solutions. By the end of the first semester the team should:

- Understand how a PUF operates
- Qualified the test equipment showing consistency in its ability to measure across all intended temperature ranges
- Develop data collection and reporting methods to ensure consistency throughout the project.
- In collaboration with BRDIG, establish the initial test plans for the material
- Tested PUF arrays from at least one wafer using various test conditions
- Report the test results indicating which PUF elements require further investigation by BRIDG
- Identified challenges with probing/testing and suggest how they may be improved upon
- Create a go/no-go testing procedure to quickly identify functional arrays
- Develop a milestone timeline for the following semester
- Provide a written report on the status of the project, initial findings, what they have learned and what they believe they can accomplish in the next semester.

Challenges during the initial semester may revolve around learning how to determine valid test data is being collected, how to optimize the testing routines to minimize time and being able to discern testing problems from device variation.

During the second semester, the team will continue to meet with the BRIDG engineers via conference call. Testing and evaluation of the various PUF devices and wafers will be explored in more detail during the second semester. The goal for the second semester is for the team to act as a Product Development Team suggesting how this product would move forward into production. The team would need to be able to provide a list of recommendations and findings which define the PUF along with items which need to be addressed if moved into production. Items to include in the report can include:

- Expected randomness within a wafer and across lots
- Feature size/dimension for moving into production
- Expected IV responses under various test conditions and temperatures
- Suggested optimal test parameters

By the end of the second semester, the team will deliver a final report detailing their findings and recommendations.

Satisfaction Standards

Exemplary-The team operated in a consistent and logical manner, established timelines and agreed upon goals were met. All the necessary test conditions, equipment and methods are in-place for moving the product forward. From a company perspective, the company would move forward with the next stage of the PUF product.

Good-The team was organized but was unable to meet all but one or two established timelines and goals which were within the team's control. Documentation is nearly complete or no clear conclusions can be drawn. From a company perspective, the program can move forward with only one or two follow on tasks.

Fair-The team was able to make progress but had poor documentation for the program and cannot make any conclusions due to incomplete or poorly organized data. From a company perspective, the company would need to allocate further resources to complete the program.

Poor-the team was not able to collectively perform as a group and meet the goals and timelines. From a company perspective, the program would need to be repeated.

Team Skills

The team will be expected to perform testing and data analysis. Students should be familiar with interfacing and controlling test equipment such as current supplies, multimeters or source measurement units. During this program, a large amount of data will be collected and will need to be analyzed to prove hypothesis. Familiarity with statistics and data processing will be as equally important.

Equipment

No additional test equipment beyond what is available at NAU should be required. Additional processes such as cross-sectioning or SEM analysis will be performed by BRIDG.