UNC CHARLOTTE
The WILLIAM STATES LEE COLLEGE of ENGINEERING
Industrial Solutions Laboratory

Company Information

Company Name	*Electric Power Research Institute (EPRI)*	**Date Submitted**	*05/03/2021*
Project Title	A Better Approach to Vegetation Management at Utility-Scale PV Plants **(EPRI_MAIN6)**	**Planned Starting Semester**	*Fall 2021*

Senior Design Project Description

Personnel

Typical teams will have 4-6 students, with engineering disciplines assigned based on the anticipated Scope of the Project.

Please provide your estimate of staffing in the below table. The Senior Design Committee will adjust as appropriate based on scope and discipline skills:

Discipline	Number	Discipline	Number
Mechanical	3	Electrical	2
Computer	2	Systems	
Other ( )			

Company and Project Overview:

The Electric Power Research Institute (EPRI) conducts research, development, and demonstration projects for the benefit of the public in the United States and internationally. As an independent, nonprofit organization for public interest energy and environmental research, we focus on electricity generation, delivery, and use in collaboration with the electricity sector, its stakeholders and others to enhance the quality of life by making electric power safe, reliable, affordable, and environmentally responsible.

EPRI has collaborated with the electricity sector and its stakeholders since 1972 and our membership has grown to represent approximately 90% of the electric utility revenue generated in the United States and extends to participation in more than 38 countries. The worldwide membership that supports our work comprises more than 1,000 organizations. While most members are electric utilities, others are businesses, government agencies, regulators and public or private entities engaged in some aspect of the generation, delivery, or use of electricity. Through their advisory roles in EPRI, its research sectors and programs, EPRI members help inform the development of EPRI's annual research portfolio, identify critical and emerging electricity industry issues, and support the application and technology transfer of EPRI's research and development. This project is a follow-on project to develop an automated way to maintain the grass at PV power generation sites.

UNC CHARLOTTE
The WILLIAM STATES LEE COLLEGE of ENGINEERING
Industrial Solutions Laboratory

One significant cost associated with maintenance of large-scale photovoltaic (PV) plants is vegetation management. In temperate climates, some vegetation can grow 10+ inches per week. If not maintained on a regular basis, the vegetation can shade PV modules, which may reduce energy production and plant capacity. Additionally, irregular shading of PV modules can cause hot spots, which is a safety/fire hazard. Plant maintenance providers have tried a litany of conventional and unconventional approaches with inconsistent success over the relatively large footprint of PV plants (a 100 MWdc plant requires nearly 500 acre and as “the best land” for solar becomes developed, the number of acres for a similar sized site can be higher). For instance, regular mowing can launch rocks into modules breaking the front glass (exacerbating O&M costs further), sheep are picky plant eaters requiring additional oversight by shepherds and guard-donkeys (for protection against prey animals), and goats chew on wiring and climb on PV module mounting structures breaking the front glass. Chemicals have been used with the risk on environmental degradation.

Previous Work by Senior Design Teams:

The team has consisted of a multidisciplinary group of mechanical, electrical, and computer engineering students. Initiated in the 2016/2017 school year by @Michael Bolen, EPRI-MAIN5 is one of the longest standing and continuing UNCC Senior Design projects.

- 1st year challenged students to develop a better way of maintaining vegetation at large-scale solar PV plants with an autonomous machine.
- 2nd year challenged students to create a non-permanent, stand-alone, re-charging system that was able to be transported in a pick-up truck.
- 3rd year challenged students to merge the systems with operational software using the Arduino single-board computer and was interrupted when the primary student developer lost his visa and had to move home.
- 4th year included an "Industry Supporter" change and continued with development of operational software including upgrading the machine's on-board computer from an Arduino to a Raspberry Pi. It challenged the students to leverage what they learned in programming language C to use Python for creating the operational software. Hardware upgrades were completed but autonomous operations software still lagged.
- 5th year coalesced all the previous efforts and learnings and the results can be seen here:

EPRI-MAIN5 “Video Expo”:

https://vimeo.com/520696581/60c6f92b3c

UNC CHARLOTTE
The WILLIAM STATES LEE COLLEGE of ENGINEERING
Industrial Solutions Laboratory

Project Requirements:

This project intends to improve the existing capabilities of the "mowbot" in 3 areas:

1. *Mechanical Engineering* - Apply lessons learned from the field-testing to create a "scaled-up" system *design* focused on improving mowing effectiveness, increasing cut-area per charge, and facilitate re-charge docking.
    a. Variable terrain navigation
    b. Blade cut quality & efficacy
    c. Clipping exhaust
    d. Power-usage per/acre reduction
2. *Computer Engineering*- Increase the on-board computational capabilities by replacing the primary "executive" single-board computer and re-loading the existing operational software to facilitate exploration and development of "computer-vision-based object detection module" and "re-charge docking module".
    a. Python capable single-board computer (SBC) with integrated graphical processing unit (GPU)
    b. Machine learning
3. *Electrical Engineering* - Adapt the electrical design to support new hardware in coordination with ME and CE teammates.
    a. Printable circuit board (PCB)
    b. Systems integration

It must:

1) Retain and build upon existing python-based modular software developed by EPRI-MAIN5 in such a way that new firmware and software "modules" are "standardized"

2) Be capable of mowing all areas of a PV plant, including under the modules and around the racking

*New unit physical design requirements to be established with Industry Supporter upon kickoff

3) Be quickly and easily sited and configured at a PV plant and not damage the PV site and equipment

4) Be reliable, autonomous, and dispatchable

5) Aim to mow grass at a cost of $250USD per acre per year

Scope and Approach

The 6th phase is intended to build upon 5 years of continual improvement and offer students the opportunity to engage in a challenging, multidisciplinary engineering project that will prepare them for their future careers.

Despite unprecedented events related to a global pandemic, the first real-world tests were conducted in April 2021 at an operational, large-scale PV plant with success, while identifying practical mechanical and navigational improvements needed such as:

Mechanical re-design for manufacturing:

- a Mowbot2 and ChargeStation2 design should be completed and fabrication/manufacturing strategy should be developed, including estimate of cost in conjunction with at least 2 contract manufacturers

    - lift the unit to decrease drag against short grass, allow grass to 'in-feed' toward the blades, and reduce battery drain/current required

    - blades must cut and exhaust grass

    - bump-stop sensitivity needs to be tuned if kept

- a prototype charging station should be designed and fabricated early-on in order to allow "docking" field tests to occur with existing mowbot

Computer upgrades toward machine intelligence and alerting:

- upgrade primary processor hardware, reload existing operational modular software, and demonstrate current functionality on existing mowbot platform
- add cameras to enable computer vision and ability to classify objects, to enable object avoidance and re-charge docking
- focus on "re-charge docking" algorithm development with current mowbot to enable effective mechanical design of Mowbot2

Electrical upgrades to facilitate integration of planned new hardware:

- focus on system reliability and ability to field-repair
- focus on 're-charge docking' and ChargeStation2 planning/prototyping

Expected Deliverables/Results:

- A working prototype that incorporates the above direction.

- Fully quoted manufacturing package based on minimum of two quotes for significant items.
- Fabrication skills to build improved version of MowBot.

Disposition of Deliverables at the End of the Project:

The prototype system and a technical write-up of the system would be demonstrated at the Expo and transitioned to EPRI after the conclusion of the Expo.

List here any specific skills, requirements, specific courses, knowledge needed or suggested (If none please state none):

- Solid modeling - CAD
- Autonomous navigation
- Fabrication skills to build improved version of MowBot.