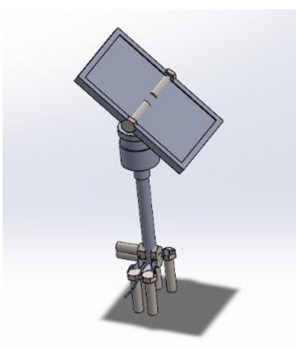
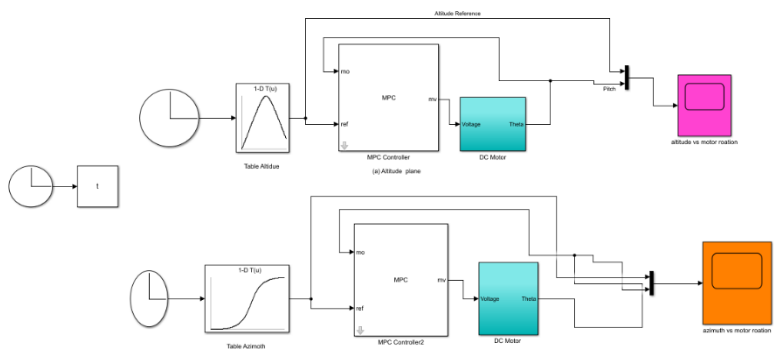
EE3204 – Engineering System Design

Project Report

Dual-Axis Solar Tracker for Maximum Power Generation

Group 14





Group Members-

- 230401L - MATHTHEGAMA M.R.L.S.
- 230409T- Mendis T.A.S.D
- 230416L - MUHAMATH M.A.A.A.

Executive Summary –

This project report presents the planning, execution, and management of the *Dual-Axis Solar Tracking system for Maximum Power Generation* project. The project was carried out as part of the undergraduate engineering curriculum with the objective of improving solar energy harvesting efficiency through intelligent panel orientation. The project was completed within the allocated academic timeframe by a three-member team through effective task allocation, time management, and coordination. All planned milestones were achieved successfully, including system modeling, control design, simulation, and documentation. The project met its technical and managerial goals and demonstrated the potential of a low-cost, efficient dual-axis solar tracking solution.

Project Background and Objectives-

The motivation for this project arises from the efficiency limitations of fixed-position photovoltaic panels, which are unable to continuously align with the sun's movement throughout the day. Literature and industry practices show that dual-axis solar tracking systems significantly improve energy capture. However, most existing solutions are expensive and complex. This project was initiated to explore a cost-effective and efficient dual axis tracking approach using **Advanced Model Predictive Controller**. The main objectives were to design a solar tracking concept, implement an appropriate control strategy, verify performance through simulation, and effectively manage the project within the given study constraints.

Project Scope-

The scope of the project includes literature review, system conceptualization, mathematical modeling of the solar tracker, control strategy development, MATLAB/Simulink-based simulation, and CAD(SolidWorks) visualization of the mechanical structure. Performance evaluation was performed through simulation results. Hardware fabrication, field testing, and long-term energy yield analysis were considered beyond the scope of this project due to time and resource constraints.

Project Organization and Team Structure –

The project was executed by a three-member team with clearly defined roles and responsibilities. Although all members contributed to multiple aspects of the project, individual leadership roles were assigned to ensure accountability and efficiency.

- **Maththegama M.R.L.S. (230401L)-** Responsible for the 3D computer-aided design (CAD) modeling of the dual axis solar tracking system using SolidWorks. This included designing the mechanical structure, panel mounting assembly, and axis support components, ensuring proper alignment, mechanical stability, and feasibility for practical implementation.
- **Mendis T.A.S.D. (230409T)-** Led literature review and research study, including reading and analyzing related research papers on dual-axis solar tracking and Model Predictive Control to derive suitable system concepts and design ideas. Played a key role in idea formulation and technical guidance, supporting the team during the MATLAB/Simulink simulations through constructive technical inputs. Additionally, handled the LaTeX-based documentation and final manuscript preparation, ensuring proper structuring, formatting, and compliance with IEEE publication standards.
- **MUHAMATH M.A.A.A. (230416L)-** Contributed to the design, modeling, and simulation of the dual-axis solar tracking system. This included developing the mathematical model of the azimuth and elevation axes, implementing the control strategy in MATLAB/Simulink, and integrating the motor dynamics with the reference generation for sun-tracking. Additionally, assisted in simulation analysis, result validation, and system performance evaluation to ensure accurate tracking and improved energy harvesting.

Project Planning and Timeline-

In the initial stage, a structured project plan was developed, outlining key milestones and deadlines. The project is divided into phases including topic selection, literature review, system design, simulation, analysis, and report preparation. A timeline was created to track progress and ensure timely completion of tasks. Minor schedule adjustments were required due to the learning curve associated with implementing Advance model predictive controls; however, these were managed through parallel task execution and effective time allocation. The project was completed within the planned study period.

Activity	September (W4)	October (W1-W4)				November (W1-W4)				December(W1-W4)			
Problem Selection	●												
Literature Review		◯	◯	◯	◯	◯							
MATLAB Simulation						●	●	●	●	●			
SolidWorks Modeling								●	●	●			
Documentation											●	●	●

Legend:

● -> **Deep Work:** Time spent building and completing tasks.

◯-> **Getting Ready:** Time spent researching and planning.

Resource Management-

This project mainly used human and software resources. Each team member contributed technical knowledge, analytical skills, and time to achieve project goals. MATLAB/Simulink was used for system modeling and simulation, SolidWorks for CAD design, and LaTeX for documentation. Since the project was simulation-based, no major financial resources were required. This approach aligned with the project's goal of developing a low-cost and resource-efficient solution.

Risk Management-

Building this simulation in MATLAB and Simulink was a huge lesson in troubleshooting. Our first major problem was the solar position data. The equations we used initially created these sharp spikes that would have been trouble for a real motor, making the whole system move in an error. We ended up refining the math to smooth things out and added a slew rate limit to keep the movements smoother.

The motor modeling was another harder since we didn't have the hardware on hand yet. We spent quite a bit of time finding through manufacturer data sheets to find exact values for friction, inertia, and torque constants. Changing our generic guess numbers for these realistic specs was a good solution point. It finally stopped the system from oscillating and made the virtual movement feel authentic.

We also hit some snags with the MPC controllers for azimuth and elevation. Early on, the solver kept crashing because our constraints prediction windows were too long. We found a stable middle ground by easing the constraints and shortening the horizon length. After cleaning up some dimension mismatch errors between our MATLAB scripts and the Simulink blocks, the loops finally stabilized. We also realized natural sunlight doesn't flicker instantly, so we filtered the irradiance input to reflect real weather transitions. All these iterative fixes resulted in a high-fidelity simulation. This facilitated early detection of errors and therefore reduced the effects of threats posed by errors and time constraints.

Quality Assurance and Validation-

The quality assurance aspect was maintained through the validation of simulation models, confirmation of reference tracking simulation results through mutual reference result checks, and system design similarity with simulation results. The simulation models were run several times to ensure system stability for accurate tracking. There were team peer reviews to enhance simulation result authenticity, result transparency, and written report quality.

Outcomes and Performance Evaluation-

The project objectives were successfully achieved. The solar tracking control using the two-axis solar tracking system demonstrated efficient tracking of azimuth and elevation angles by the model predictive control in the simulation. Performance analysis showed that there were no distorted motor responses and that the tracking error was small, thereby using less control effort. This compares favorably with the literature and validates the strategy used. Although no hardware setup was performed, the results are sufficient for advancement.

Challenges and Lessons Learned-

One of the most challenging aspects that the team encountered is the complexity involved in the implementation of the Model Predictive Control algorithm. Another challenging aspect is the planning that had to occur to ensure that the technical activities are undertaken within the allocated timeframe. The project explains the significance of planning, teamwork, and execution in the success of any project.

Project Status and Completion-

The project has been successfully completed, and all planned deliverables have been delivered within the academic schedule. The objectives of system design, simulation, analysis, and documentation were fully achieved. The project is considered complete for the current scope, with opportunities identified for future improvement through hardware implementation and experimental validation.

Conclusion and Recommendations-

Finally, this project shows good project management and good engineering practice in the implementation of a dual-axis solar tracking system. Such an example of good project management practice has made it easy for us to conduct this project. To improve the practicality of this system, I recommend that in future projects be done on hardware implementation in real time, sensor fusion, and energy harvesting.