

The Design-Build Term Project Illustrating MATLAB Application to Wind Farm Design and Analysis

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Introduction and Objective:

This poster paper¹ presents the design-build wind farm term project that is part of a course on engineering problem solving using software tools, primarily MATLAB. The course, Engineering 1221, is a second year, two credit hour, semester course where students enter the course with some expertise in using MATLAB and Excel.

It is one of seven poster papers about goal directed course design². This course design method begins with a statement what students should know and care about upon successful completion of the course. This statement is followed by identifying observable and measurable learning objectives were identified that are aligned with the course goals.

The term project engages students in a group learning activity where individual team members are responsible of portions of the project as designated by the work breakdown structure that the team develops. The aim of this paper is evaluation of the design-build term project's contribution to achieving the stated course learning objectives.

Method:

During the second week of the semester, students are grouped into teams for the term project. Each student team forms a mock design-build engineering firm. The teams develop and deliver a wind farm design and construction schedule using the iterative, incremental design method³. The 13 figures on this poster paper illustrate both the method of solution that students use in designing and planning the construction of a wind farm, and in presenting the end results. Each figure is framed in the color associated with the primary learning objective exhibited as follows: THINK (coral), USE TOOLS (purple), DESIGN (lime), CONDUCT (turquoise), COMMUNICATE (orange).

Planning and executing this project was done using the iterative, incremental design method shown in Figure 1. Each iteration of the design consisted of four distinct stages:

1. *Observe and evaluate design*; the team members individually evaluated the design according to a rating system based on a list of project criteria that included: cost, safety, environmental impact, location suitability, and scheduling. The ratings were then tabulated and an average score was given to each project component.

2. *Define the problems*; based on the assigned ratings, problem areas could easily be identified and weak design elements highlighted. To clearly define a problem, the team worked to answer a series of questions designed to bring to light any hidden weakness. Are goals being met? Is the design efficient? Are technical details adequately addressed? Have any relevant considerations been overlooked?
3. *Develop the solutions*; with the problems clearly defined, a list of possible solutions was made using brainstorming techniques. The team met in a relaxed environment where all ideas were accepted without any initial evaluation. Once a list was made, each idea was evaluated by the group and a solution was selected based on its ability to satisfactorily address all aspects of the problem.
4. *Implement and test the solutions*; each solution was implemented and thoroughly tested by running cost and performance analyses, reworking schedules, and examining the overall project to ensure that other conflicts had not been created as a result of the changes.

Results:

This poster paper displays a representative structure of the final wind farm design. The figures are framed in colors representing the primary learning objective of the figure as follows:

- 1. THINK** (coral): *Demonstrate ability in critical, creative and practical thinking through algorithm design, MATLAB software design and evaluation.* **For example:** Understanding how MATLAB is used to simulate and optimize the wind farm design; and, developing algorithms to solve the “technical challenge” assignments that are part of the wind farm term project.
- 2. USE TOOLS** (purple): *Utilize MATLAB software tools to solve engineering problems.* **For example:** Using MATLAB tools for design and analysis of a wind farm; and developing MATLAB tools for design and analysis of a wind farm.
- 3. DESIGN** (lime): *Demonstrate the ability to create and design within the constraints of time, cost, quality, safety, and environmental impact.* **For example:** Design is the fundamental process in conducting the wind farm design-build project. The design process is rooted utilization of MATLAB interactive budgets and schedule charts for optimization of projects constraints such as time, cost, quality, safety, and environmental impact.
- 4. CONDUCT** (turquoise): *Work individually, in pairs, and on teams to solve engineering design and analysis problems professionally and ethically.* **For example:** The success of term project and the Team Labs that support it depend upon effective teamwork. This not only includes use of team management tools such as schedules and work breakdown structures, but also learning the habits of ethical, productive, and positive team roles.
- 5. COMMUNICATE** (orange): *Demonstrate skill in technical communication related to engineering and software development.* **For example:** Effective teamwork requires excellent communicating skills. Team members develop the habits of good team communications through

a multitude of different channels including weekly meetings, email, messaging, and shared electronic work breakdown structures and schedules.

The following figures illustrate the connection between course content and student learning objectives. The central, educational goal of the wind farm term project is application MATLAB and engineering design and analysis techniques to the real world problem of alternative energy⁴. This central goal is presented in Figure 1.

Figures 2 through 6 show the application of the iterative, incremental design method in developing the final design. The final design endeavored to address limitations specific to wind energy such as location, cost, maintenance⁵, and profitability⁶. Figures 7 through 10 give details of the wind farms location, choice of turbine, and general layout including connection to the power grid. Finally, Figures 11 through 13 show how cost and projected profit were analyzed using theoretical power calculations and historical data.

MATLAB was utilized throughout the process to analyze data and create schedules such as the Gantt chart in Figure 5. MATLAB's graphing capabilities were especially useful for creating 3-D models of turbine performance based on average wind speeds shown in Figure 3. Upon completion, the project was academically successful in the following ways:

1. Met all term-project requirements;
2. Proposed a workable solution to the wind farm design problem;
3. Successfully identified and addressed the relevant universal constraints (Time, Cost, Safety, Environmental Impact, Quality);
4. Utilized MATLAB to model wind farm performance and analyze revenue verses cost; and,
5. Effectively packaged the design solution in a presentation that employed techniques of good communication such as clear formatting, adequate technical detail, engaging graphics, and straight-forward organization.

Conclusions:

Ultimately, the scope and value of the wind farm project extended far beyond its academic result. Naturally, it provided stimulating insight into the benefits and difficulties of renewable energy and the science behind extracting power from the wind. Topics studied as part of the project included wind power theory, the Betz Limit, turbine design constraints, and environmental impact. The ensuing study of these topics supports the first course learning objective: *Demonstrate ability in critical, creative and practical thinking through algorithm design, MATLAB software design and evaluation.*

Application of these topics to design and analysis of the wind farm resulted in students meeting the second and third learning objectives: *Utilize MATLAB software tools to solve engineering problems;* and, *Demonstrate the ability to create and design within the constraints of time, cost, quality, safety, and environmental impact.*

As a natural result of working closely in a group for an extended period of time, each member also gained valuable teamwork experience. Topics that were discussed in class, such as roles, organization, and conflict management, were given practical application in the group setting. Success of the term project was built on a foundation of effective teamwork. More than any other learning activity, the term project directly lead to meeting the forth learning objective: *Work individually, in pairs, and on teams to solve engineering design and analysis problems professionally and ethically.*

Utilizing effective technical communication skills worked hand in glove with teamwork in laying the foundation for project success. This aspect was the most beneficial and simultaneously challenging part of the wind farm project. Only with good communication could the work be coordinated among team members so as to complete each design stage on time according to the predetermined project schedule. By creating weekly work agendas and staying in touch electronically, each team member learned to work autonomously while maintaining communication and reaching designated goals.

Equally important to the ultimate success and acceptance of the project, were the technical communication skills learned in preparing for, and delivering the final term project slide presentation. Students learned techniques to capture audience attention and maintain this connection throughout the talk. Both execution of the term project and its final presentation are tied to the fifth learning objective: *Demonstrate skill in technical communication related to engineering and software development.*

Similarly, the wind farm project provided an opportunity to apply skills such as computer programming, research, and mathematical analysis to real world situations. This ability is fundamental to success in any upper level, discipline specific engineering classes. In light of the future, this project has provided valuable experience working in a team setting with broad, open ended design goals where problems must be defined and viable solutions obtained within a specified time frame. Although the project had limitations of time, detail, and readily available data, the overall experience was made more valuable through working around these limitations to reach a solution.

In conclusion, the term project engages students in using MATLAB as problem solving tool and as a means of technical communications, in a setting which fosters teamwork and cooperative learning.

References:

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