



COURSE Project (25%)

2020-2021

Combined Cycle Power Plant

Thermodynamics II

ME 300

Semester: Spring 2021



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I. Introduction

Projects for engineering students give an edge over the race of recruitment to work hard to ensure a good career. In spite of employment practices in recent times, students are progressively taking up projects to pad up their skill-set. Engineering projects help students to learn and acquire practical knowledge. Despite of theory concept they acquire, various industries also need to know their capacity to complete projects using their specific initiatives. Thus, we recommend students to realize engineering projects in their four years of engineering and try to present as many white papers as possible. Students who give importance to their course projects are expected to learn how to:

- Work in teams including multidisciplinary teams
- Build a major design experience based on the knowledge and skills acquired in the course work
- Build a major design experience incorporates appropriate engineering standards and multiple realistic constraints
- Apply both analysis and synthesis in the engineering design process, resulting in designs that meet the desired needs

In the design process, both creativity and criticism are essential. The followings are the seven steps that students should consider while designing their projects:

- Recognition of the need and identifying opportunities: Every project begins with recognition that needs improvement. These needs may be obvious or hidden to be revealed by investigation, surveys or research.
- Definition of the design problem: It is a major task requires gathering information about the problem.
- Definition of the design criteria and constraints: While the problem is being defined, the design criteria and constraints must be defined
 - a. Design criteria are performance standards to be met by the design
 - b. Design constraints are limitations placed on the designer, the final design or manufacturing process. *Examples of possible constraints include accessibility, aesthetics, codes, constructability, cost, ergonomics, extensibility, functionality, interoperability, legal considerations, maintainability, manufacturability, marketability, policy, regulations, schedule, standards, sustainability, or usability.*
 - c. Risk analysis
- The design loop: design is a repetitive process of:
 - a. Synthesis (Brainstorming - Generating new ideas)
 - b. Analysis (Breaking ideas – find expected results)

- c. Decision-making (Deciding the best alternative)
- Optimization: Design team must ask themselves if it is the optimum design. Optimum is the best design that can be achieved at reasonable cost. The proposed design is judged against the design criteria
- Evaluation: Design team should hold a design review to approve drawings and specifications before they are released. If an optimum design cannot be achieved, the design team might revise the problem definition, the design criteria or the constraints in order to achieve the optimal solution or prototype.

II. Project Description

The design project involves a combined gas-vapor power cycle. The cycle is illustrated in the figure below; basically it involves the recovery of the exhaust gases from a gas turbine cycle (which are typically at a high temperature) to provide the heat to the boiler in a steam turbine cycle. Therefore, a combined-cycle power plant uses both a gas and a steam turbine together to produce up to 50 percent more electricity from the same fuel than a traditional simple-cycle plant. The waste heat from the gas turbine is routed to the nearby steam turbine, which generates extra power.

Below is how a combined-cycle plant works to produce electricity and captures waste heat from the gas turbine to increase efficiency and electrical output.

1. Gas turbine burns fuel.

- The gas turbine compresses air and mixes it with fuel that is heated to a very high temperature. The hot air-fuel mixture moves through the gas turbine blades, making them spin.
- The fast-spinning turbine drives a generator that converts a portion of the spinning energy into electricity.

2. Heat recovery system captures exhaust.

- A Heat Recovery Steam Generator (HRSG, the boiler in the figure below) captures exhaust heat from the gas turbine that would otherwise escape through the exhaust stack.
- The HRSG creates steam from the gas turbine exhaust heat and delivers it to the steam turbine.

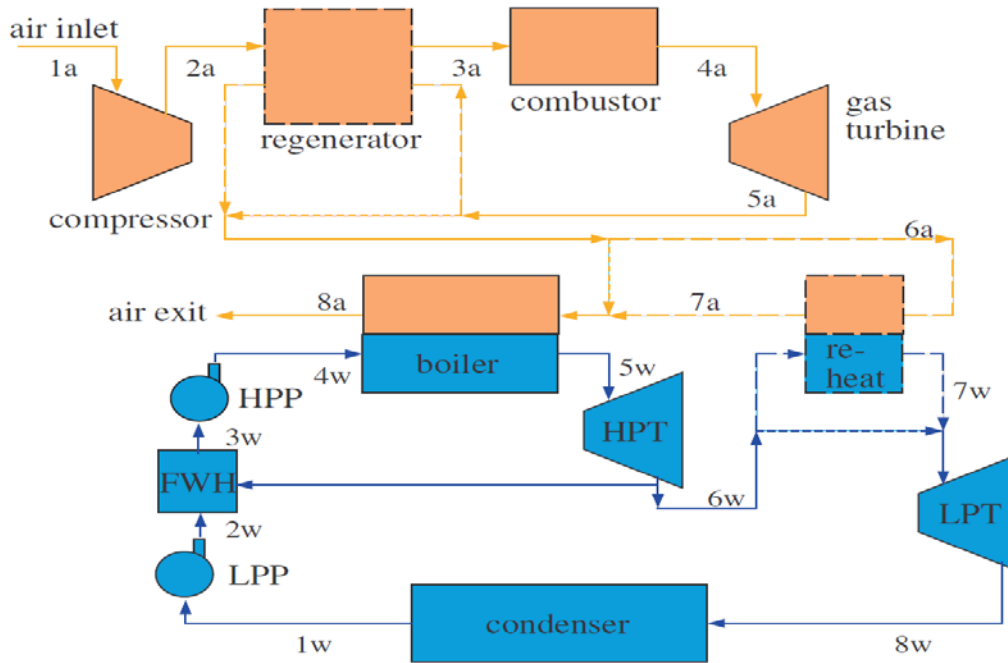
3. Steam turbine delivers additional electricity.



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- The steam turbine sends its energy to the generator drive shaft, where it is converted into additional electricity.



Project Summary (Scenario)

The gas turbine system consists of a standard Brayton cycle with optional regeneration (note that the dotted lines in the schematic will correspond to optional features in your design). The vapour power system is a standard Rankine cycle with one open feed water heater and optional reheat between the high and low pressure turbine stages.

Fixed conditions for the system components are as follows:

Air cycle: Air enters the compressor at 300 K and 1 atm pressure, and exits the combustion chamber at a temperature of 1300 K. The compressor and the turbine are both adiabatic, and have isentropic efficiencies of 0.8. The regenerator, if present, has an efficiency of 0.9.

Steam cycle: The condenser pressure in the steam cycle is 50 kPa. The pumps can be assumed isentropic, and the turbines have isentropic efficiencies of 0.85. The exit from the FWH is a saturated liquid at the FWH pressure. The boiler has an effectiveness $\epsilon = 0.9$, which is defined so that the actual heat transfer in the boiler (either coming from the air or going to the water) is

$$\dot{Q}_B = \epsilon \dot{m}_a [h_a(T_{7a}) - h_a(T_{4w})]$$

in which T_{7a} and T_{4w} refer to the inlet air and water temperatures (shown in the diagram), \dot{m}_a is the mass flow rate of air, and h_a is the enthalpy evaluated for the air. An additional piece of information provided by the boiler manufacturer is that

$$T_{5w} = T_{7a} - 30 \text{ }^\circ\text{C}$$

i.e., the water exits the boiler at a temperature 30 °C lower than the air entering the boiler. This same relation applies to the reheater, if present.

The objective of the project is to design a combined system that will produce a net power output of $\dot{W} = 1000 \text{ MW}$. Constraints on the design parameters of the system are:

- The pressure ratio of the gas cycle can range from 8 to 14.
- The maximum allowable steam temperature, at the inlet to either the HP or LP turbine, is 600 °C.
- The maximum boiler pressure is 10 MPa.
- The minimum quality at the turbine exits is 0.95.

The foremost goal of the design is to maximize the overall thermal efficiency of the system. A secondary goal is to minimize the total flow rate of air and water. The first goal relates primarily to the operating cost of the system; a higher efficiency will produce more power for less fuel. The second goal, on the other hand, relates (somewhat) to the capital costs of the system, in that a larger flow rate will correspond to larger (and more expensive) system components. This two goals are not complementary; a higher efficiency may come at the expense of a higher total flow rate.

The report must include a description of the problem, the relevant formulas and methods for analysis of the system, and a detailed presentation of the analysis for at least one design (it can be a preliminary design or your final design). A table and/or plot of thermal efficiencies and mass flow rates for a range of preliminary designs should be given, and the rationale you use to select the final design should be clearly described.

Required specifications for the design include:

1. The mass flow rates of the air and the water.
2. The gas turbine pressure ratio.
3. The steam cycle boiler pressure, turbine inlet temperatures, FWH pressure, and FWH bleed fraction (the fraction of steam that is bled from the exit of the HPT and directed to the FWH).

4. A hand calculation should be carried out and then validated by using the Interactive Thermodynamics (IT) software and CyclePad software.

The grade will be given based on the performance of your design and the accuracy of your calculations.

III. ABET Learning Outcome

The aim of this project is to maximize the overall thermal efficiency of the system. A secondary goal is to minimize the total flow rate of air and water.

1. *Apply the laws of thermodynamics to analyse and improve thermodynamic cycles including vapor and gas power cycles, refrigeration cycles, and heat-pump (1*, 4*)*
2. *Develop mathematical formulations for the properties of ideal gas mixtures(1*)*
3. *Apply the laws of thermodynamics to basic heating, ventilation and air conditioning systems. (1*)*
4. *Apply the laws of thermodynamics to basic combustion processes. (1*, 4*)*

** 1: An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.*

** 4: An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.*

IV. Project Management & Deliverables

This project is divided into the following deliverables.

Deliverable 1: Project report (due date is end of week 08):

- Students of each class need to form project groups (group of 3 or 4 depending on number of students)
- Each group of students will be assigned a theme/subject for the project. Students are requested to choose/search for an idea related to the assigned theme.
- Students should talk about the problem definition and the objectives of the project.

- Students should write a literature review about the combined cycle power plants and select a preliminary design based on the literature.
- Students should analyze their study and conclude.

Deliverable 2: Final report /simulations/research product/etc. (due date is end of week 12):

- Students are required to propose a design regarding the project which includes a detailed calculations and full schematic for the proposed combined power plant.
- A scientific report must be written and submitted. The provided template should be used. The report should begin with a discussion and conclusion. It should contain the same headings as in the presentation, with more details given.
- The report should include the full analysis of the project
- Students should clarify the followed learning strategy in order to get an optimum solution/design/knowledge of their work
- A calculation/simulations results must be done by each group and submitted in the final report.

Deliverable 3: Oral Presentation (due date is week 14):

- The presentation duration is 10 minutes that is followed by 5-10 minutes of a discussion period. All presentations must be done using presentation software like MS PowerPoint. An electronic copy of the presentation and report must be submitted through Moodle (Turnitin) prior to the presentation due date. A rough structure of oral presentation is as follows:
 - a. Introduction
 - b. Project Overview and Project Statement (Explanation of project goals and aims)
 - c. Steps and methods involved in the project
 - d. Representation of final product (Prototype, creative product, simulations or research product exc.)
 - e. Reflections of the project on students' learning
 - f. Conclusion and Future Remarks
 - g. References

V. Turnitin



Turnitin is a web-based solution that lets AUM faculty and AUM students check written work for improper citation or misappropriated content. You may be assigned a username and a password to be able to upload your assignments online, when and if requested. If you face any technical problem, please contact IT at AUM.

VI. APA Style

AUM adopts the APA writing style for all its academic programs. AUM students need to use this style for their assignments. The following web site is of value for students: <http://owl.english.purdue.edu/owl/resource/560/01/>. Students are also encouraged to visit the AUM Writing Lab to receive help and guidance on all APA-related questions.

VII. Academic Honesty and Integrity Assurance

One of the signs that the course material has been properly understood is honesty when accomplishing the assignments. Lack of academic integrity (e.g. plagiarism, copying another person's work, the use of unauthorized aids on examinations, cheating, facilitating acts of academic dishonesty by others) will not be tolerated. Therefore, if students include ideas, sentences, or other material that are not theirs in their work, they must properly quote the source(s). Students are encouraged to consult with the instructor if they have any questions on the issues of academic integrity or technical formatting of the references.

Upon suspicion and doubt of the authenticity of the work submitted, the Instructor has the right to ask the student to verify her/his work. This can be done through, but not limited to, repeating the work, oral examination or discussion, alternative or similar on spot class assignment, pop quiz, or any other action deemed necessary. If the student fails to prove the authenticity of the work, then the Instructor will apply the academic misconduct rules as mentioned in the AUM Student Handbook which may include awarding the work a zero grade.

Students are expected and encouraged to be honest and to maintain the highest standards of academic integrity in their academic work and assignments at the University. Any act of Academic Dishonesty may result in severe consequences for violations range from zero grades given for the assignments, failing the course, and suspension from the University. Students will refrain from any academic dishonesty or misconduct including, but not limited to:

- Upon suspicion and doubt of the authenticity of the work submitted, the Instructor has the right to ask the student to verify her/his work. This can be done through, but not

limited to, oral examination or discussion, or any other action deemed necessary. If the student fails to prove the authenticity of the work, then the Instructor will apply the academic misconduct rules as mentioned in the AUM Student Handbook

- A zero grade will be given to all students that share exactly the same results: You will also be held responsible if someone else copies your work - unless you can demonstrate that you have taken reasonable precautions against copying.
- Any violation of the AUM standards will be taken as a violation to AUM policy and can lead to penalties. If you wonder whether a course of action violates this policy, simply ask in advance and please refer to the undergraduate AUM Student Handbook.

For a detailed description of academic misconduct, please refer to the AUM Student Handbook.

VIII. Copyrights

Students are expected to adhere to copyright practices, **refer to the undergraduate AUM Student Handbook.**

IX. Project and team-based work

The Project component of the course, if exist, is essential to passing this course. The project shows competency in understanding and applying the course objectives and achieving the learning outcomes. The project should allow the student to investigate, apply, research, and practice real-life business situations. It is expected that each student to fully and actively participate in the project as an effective team member. A project document will be distributed later in the semester with details about the project.

For all group related work, the **entire team is responsible for the team outcome and the deliverables**, except for the specific parts of the project that may be graded individually depending on the project's requirement and as communicated in the project document.

X. Marking Scheme

The project is worth 25% of the total grade of your course; each deliverable is worth 2.5; 12.5 and 10 %, respectively. The grade will be based on every group's work, calculation, simulations on IT and/or CyclePad. The student will be evaluated based on the below grading scheme:



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Final Report D2:

Introduction (10%)	Available Solutions (5%)	Proposed Solution (60%)	Conclusion (10%)	References (5%)	Formatting and language used (10%)
<ul style="list-style-type: none"> • Problem Definition (2.5%) • Criteria and Constraints (2.5%) • Objectives (2.5%) • Structure of the Report (2.5%) 	<ul style="list-style-type: none"> • Brainstorming (2.5%) • Advantages and Inconvenient of each solution (2.5%) 	<ul style="list-style-type: none"> • Background and Theory (5%) • Very good design With maximum efficiency and minimum flow rate (20%). very good measurements and calculations (20%). report includes all the elements (15%). 	<ul style="list-style-type: none"> • Summary of the work done. (5%) • Discussion. (5%) 	<ul style="list-style-type: none"> • APA references 	<ul style="list-style-type: none"> • Grammatical and sentence structural mistakes (5%) • Formatting: Cover page, group members' names, consistent fonts and size throughout the document (i.e. no copy-pasting from the net) (5%)

Final results:

- Design [70%]
 - a. Does the simulation work or Not? (10%)
 - b. How does the simulation look? [nice/catchy/basic design] (10%)
 - c. Results meet initial expectation? Are the outputs satisfactory? (10%)
 - d. Are the material/components used to build the prototype adequate for such problems? (5%)
 - e. Is the proposed solution the most optimized? (5%)
 - f. What is the impact of the material/components on the environment? (5%)
 - g. Explaining the engineering design process clearly based on the proposed design. (5%)
 - h. Using real illustrations extracted from simulation (graphs, tables, trends, Pictures) and proper organization using APA style (5%)
 - i. Explaining exactly the same components and elements used in the design/circuit (5%)
 - j. Clear and convincing explanation on implementation of the design (10%)
- Answering question correctly [30%].



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- a. Able to answer the questions related to the prototype and provide data to support their answers. (Accurate & detailed explanation of answer) **(15%)**
- b. Show deep understanding on the design/simulations etc., its main functionality, the implementation, etc. **(15%)**

Presentation:

Knowledge and Content (15%)	Technical methods (10%)	Results (figures, graphs, etc.) (10%)	Contribution of work (15%)	Knowledge of subject (30%)	Presentation Skills (20%)
<ul style="list-style-type: none"> Material sufficient for clear understanding and exceptionally presented 	<ul style="list-style-type: none"> Sufficient for understanding and exceptionally presented 	<ul style="list-style-type: none"> All figures clear with the same format and exceptionally explained 	<ul style="list-style-type: none"> Significance exceptionally well explained 	<ul style="list-style-type: none"> Demonstrated full knowledge; answered all questions with elaboration 	<ul style="list-style-type: none"> Excellent language skills, gestures, etc.

XI. Student Assessment Rubric

Deliverables	Bare pass mark (60%-69%)	C classification (70%-79%)	B classification (80%-87%)	A classification (>87%)
<p>D1</p> <p>Weighting 2.5%</p>	Initial report lacks clarity and missing two items	Initial report lacks clarity and missing one element	Initial report includes all items but lacks clarity	Well written initial report includes all elements mentioned in D1 above



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<p>D2</p> <p>Final report</p> <p>Weighting 12.5%</p>	<ul style="list-style-type: none"> •The report is succinct and to the point. The maximum size of the report is met. •The report includes only brief analysis. •Brief conclusion and discussion. •The writing of the report includes some mistakes. 	<ul style="list-style-type: none"> •The report gives clear details on all of the components of application. •The report includes some analysis. •The conclusion/discussion on the application partially relevant. •The writing of the report does not include mistakes. 	<ul style="list-style-type: none"> •The report gives clear details on all of the components of application. •The report includes detailed analysis. •The conclusion/discussions on the application are relevant. •The writing of the report does not include mistakes. 	<ul style="list-style-type: none"> •The report gives clear details on all of the components of application. •The report includes detailed analysis. •The conclusion/discussions on the application are relevant. •The report is well structured and it does not include mistakes.
	<p>- Acceptable design With lower maximum efficiency and higher minimum flow rate</p> <p>-satisfactory measurements and calculations</p> <p>-Poorly written report includes some of the elements</p>	<p>Good design With lower maximum efficiency and higher minimum flow rate</p> <p>- good measurements and calculations</p> <p>- Poorly written report includes some of the elements</p>	<p>Updated report includes: - Very good design With maximum efficiency and minimum flow rate</p> <p>- very good measurements and calculations</p> <p>-report includes all the elements</p>	<p>Excellent design With maximum efficiency and minimum flow rate</p> <p>- Accurate measurements and calculations</p> <p>report includes all the required elements</p>
<p>D3</p> <p>Oral presentation</p> <p>Weighting 10%</p>	<ul style="list-style-type: none"> •The presentation covered <i>most</i> of the topics in the final report. •The team Spoke clearly and made only few mistakes. •Only few questions are answered. 	<ul style="list-style-type: none"> •The presentation covered <i>all</i> of the topics in the final report. •Information is presented in logical order. •Some questioned are answered. 	<ul style="list-style-type: none"> •The presentation covered <i>all</i> of the topics in the final report. •Information is presented in logical order. •All of the questions are answered. 	<ul style="list-style-type: none"> •The presentation covered <i>all</i> of the topics in the final report. •Information is presented in logical order. •The analysis are clearly discussed and the implemented method is •All of the questions are answered.