ME343 - Thermal Fluid Systems
Semester Project Phase 1
Analysis of GE LM2500+G4 DLE Gas Turbine
Fall 2024

Overview

The University of Texas cogeneration power plant houses a General Electric LM2500+G4 DLE turbine-generator system for electric power generation. In your term project, you will develop a computer model to predict and confirm performance of this gas turbine unit under various operating conditions including the performance effects of inlet air temperature, relative humidity, load and backpressure. Your model must be flexible enough to incorporate changes in design operating parameters (e.g., turbine inlet temperature and inlet airflow) and will be used to perform parametric analysis of the LM2500 system. Figure 1 shows the overall system components and the thermodynamic station numbers for the LM2500.

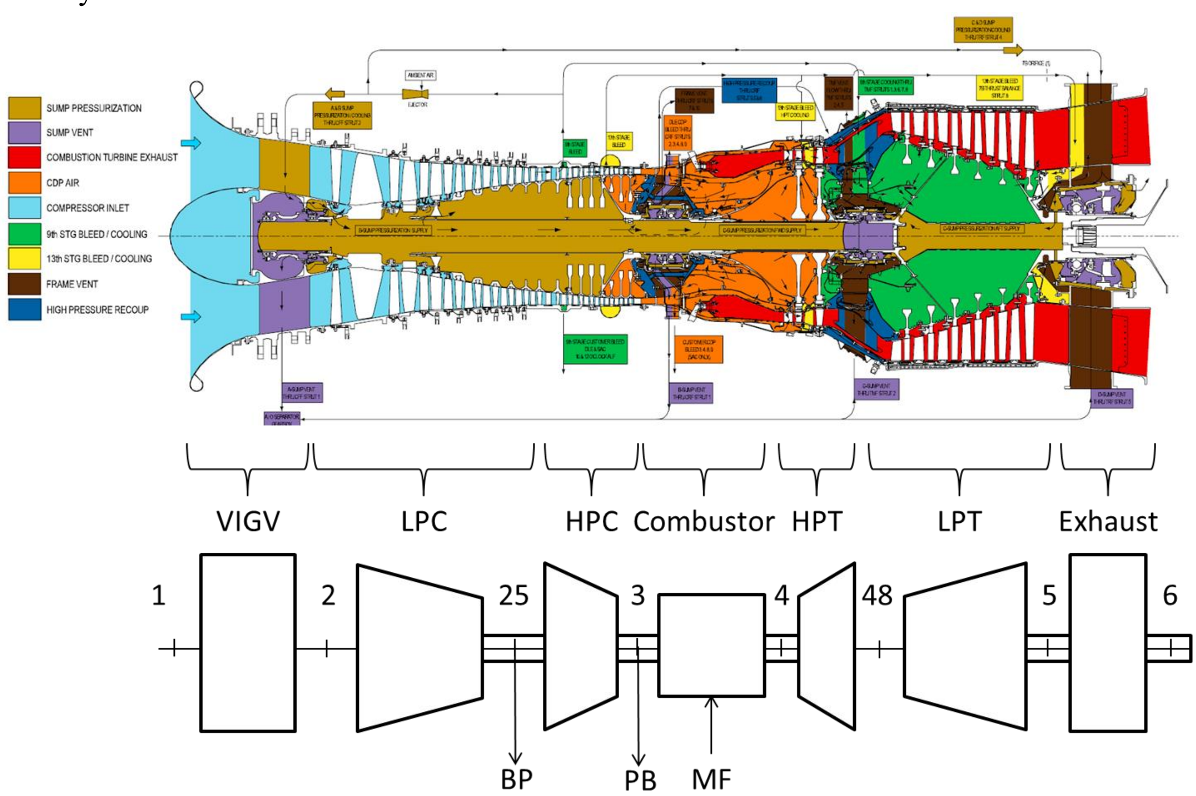

Figure 1: GE LM2500+G4 DLE thermodynamic station designations

Phase 1: A Simplified System

In Phase 1 of the project you will create and validate a simplified computer model for the turbine system. In this simplified model you will model the combustor as a heat exchanger receiving heat energy equal to the product of the fuel mass flow rate and the Lower Heating Value (LHV) of the fuel. Finally, you will validate your simplified model by comparison with manufacturer's performance calculations and UT power plant test data.

Data is provided in the Excel sheet. You are asked to pick the useful data, compare with your own results, and explain any discrepancies.

Project Task Outline (details to be provided later)

1. Using the UT libraries, the internet, and other authoritative sources investigate the general topic of stationary gas turbine engines. Write an introductory chapter of 3-4 pages, double spaced, discussing the characteristics and applications of engines of this type. Be sure to carefully reference all sources of information.
2. Formulate a general algorithm for determining power output and thermal efficiency, as well as, internal operating conditions such as exhaust composition, and pressure and temperature at specified points in the cycle. Strategies for formulating the model will be discussed in class.
3. Implement the algorithm in a Matlab-based computer model with a convenient user interface to allow variation of input parameters and output of results. Results will be presented in tabular and graphical form suitable for inclusion in your final report.
4. Benchmark the model against manufacturer's performance data. Test the effect of simplifying assumptions on the accuracy of the calculations for a set of base case conditions.
5. Perform part-load performance analyses for a range of operating conditions. This analysis will be discussed in more detail in class and additional data will be provided.
6. Investigate the general subject of NO_X production by gas turbine engines. Prepare a brief (3-4 page) background section on NO_X and control strategies.
7. Prepare a professional quality team report documenting your work on Tasks 1-6.

General Project Schedule

- Project proposal: due September 27. Deliverable: short memorandum proposal introducing the project team, giving a brief overview of the project, outlining tasks with a Gantt chart showing due dates of deliverables, and a statement of allocation of work between team members. Two-page maximum, double spaced except for Gantt chart.
- Phase 1 model: due October 21. Deliverable: Progress memorandum documenting first generation air-only model, presenting plots of requested results and hand calculations. Detailed specifications for the model will be provided separately and discussed in class.
- Final report: Plots of results are due December 6 and the completed final report is due early during the final exam period. Deliverable: complete final report as uploaded pdf file. Include Phase 2 model capable of handling varying gas composition with combustion analysis and combustion products of N_2, O_2, CO_2, and H_2O in the exhaust flow. The report is to present the results of all benchmarking calculations and case studies. The report will also include introductory and environmental chapters, and a list of references.

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Team Project Phase #1 (Due Oct. 21)
Specifications for <u>Phase 1 Model</u> of GE LM2500+G4 DLE Gas Turbine

<u>General specifications/assumptions:</u>

- Programming language: Matlab
- Working fluid: dry air (moist air will be considered in Phase 2)
- Thermodynamic properties: assume ideal gas, non-constant specific heats using polynomial fits of N_2 and O_2 for the air from the ideal gas tables (A23) as a function of temperature for enthalpy (h_i) and S^o_i
- Units: English units for all inputs, SI for all computations, English and SI for all outputs

<u>Input operating parameters (base case)</u>

- Ambient air conditions: P_0 = 14.417 psi, T_0 = 65 ºF, assume RH_0 = 0% with air molar composition of 79% N_2 and 21% O_2
- Altitude: ALT = 530 ft (not used in Phase 1)
- Inlet air mass flow rate: $\dot{m}_{air,in}$ = 189.7 lb/s (pps), for other operating conditions we will hold the volumetric flow rate constant at the base case value
- Inlet pressure loss: ΔP_{IN} (= 4 in H_2O, nominal)
- Exhaust pressure loss: ΔP_{EX}(= 10 in H_2O, nominal)
- Fuel type and lower heating value: FUEL = Natural Gas, LHV = 20,185 BTU/lb

<u>Input design parameters</u>

- LP and HP compressor pressure ratios: r_{LPC} = 6, r_{HPC} = 4
- Bypass air mass flow percent: $\%m_{BP}$ (= 0, nominal)
- HP compressor parasitic bleed air mass flow percent: $\%m_{PB}$ (= 0, nominal)
- LP and HP compressor efficiencies: η_{LPC} = 82%, η_{HPC} = 84%
- HP and LP turbine efficiencies: η_{HPT} and η_{LPT} (determine by reverse engineering of the base case)
- Generator efficiency: η_{GEN} = 97.7%
- Assume entire turbine is adiabatic
- P_{48}=71 psia (base case only)
- P_{NET} (= 30.607 MW = electrical generator power, base case) = $\dot{W}_{T2}$ * .977

<u>Output performance parameters</u>

<u>Base Case engine operating conditions</u>

Include table of temperature and pressure at each major thermodynamic station, volumetric flow rate at the inlet, and the two turbine efficiencies.

Non-Base Case engine operating conditions

Plots

The following are to be plotted vs. inlet temperatures of: 35, **65**, 85, 105°F (row 18) where you have used the corresponding fuel mass flow rates in the Excel sheet, (line 40) and the turbine efficiencies determined from the base case.

The following are to be plotted vs. $\dot{m}_F$ for 20, 40, 60, 80, and 100% of base case fuel flow rate at 65°F inlet temperature (except for $\dot{m}_F$ the other parameters are the same as the base case)

- Electrical power output: P_{NET} (= 30.607 MW, base case and is the calibration case for Turbine efficiencies)
- Mass flow rate at inlet, for constant volumetric flow rate equal to that of the base case (lbm/hr)
- Mass flow rate at outlet (lbm/hr)
- Thermal efficiency: η_{TH}
- Turbine inlet temperature (T_4, °F)
- Engine outlet temperature (T_6, °F)
- Specific fuel consumption: SFC (lb_m/kW-hr)
- Heat rate: HR, (BTU/kW-hr)

[SFC(LB/KW-hr)* LHV (Btu/LB) =Heating Rate (BTU/KW-hr)]

Technical Memorandum

To:

From:

Date:

Subject:

Objective: What are you trying to determine and why?

Procedure: How did you address the problem? What are the major assumptions? Indicate the basic principles applied, algorithms used and the calculation procedure.

Results and Discussion: The outcome of your work. Tables and Plots (your own results and comparison with UT & GE data). Refer to the tables and plots and discuss (i) what they show (ii) the trends observed.

Conclusions/Recommendations: What have you learned?

References:

Appendices:

The algorithm map (flow chart) and computer input/output listings

Tables and Plots (your own results and comparison with UT & GE data)

Sample calculations

Numerical results

The printout of the code

Be concise and brief; get to the point.
Use this opportunity to practice your writing skills!

Project Memo for Phase 1 (due October 21)

Memo length: 2 pages of double-spaced text maximum, plus plots of Phase 1 results, plus hand calculations, plus Matlab script

Name:____Total:________/50____

_______(5) Memo: Introduction and description of assignment

_______(5) Memo: Description of the analytical and computer model

(15) Memo: Results Summary and Discussion Plot vs T_1 and vs fuel mass flow rate

- Reverse engineered HP and LP turbine isentropic efficiencies
- Electrical power output: P_{NET} (= 30.607 MW, base case and calibration case for Turbine efficiencies)
- Mass flow rate at inlet, for constant volumetric flow rate equal to that of the base case (lbm/hr)
- Mass flow rate at outlet (lbm/hr)
- Thermal efficiency: η_{TH}
- Turbine inlet temperature (T_4, ºF)
- Engine outlet temperature (T_6, ºF)
- Specific fuel consumption: SFC (lb_m/kW-hr)
- Heat rate: HR, (BTU/kW-hr)

_______(5) Memo: Summary of comparison of the computer model with manufacturer's base case simulations and data from the UT power plant

_______(10) Presentation of hand calculations for base case

_______(5) Attached copy of Matlab script

_______(5) Overall appearance and organization