2006 UTSR Industrial Fellowship Program

Final Report

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Introduction

I was appointed to Clean Energy Systems (CES) during my twelve weeks as a fellow in the UTSR Industrial Fellowship Program. While at CES I worked closely with my industrial mentor, Vic Viteri, as well as other outstanding personnel employed at CES. In my twelve week stint I worked on three main tasks and several other subtasks. The first main task to which I was assigned was the Energy Innovations Small Grant project, which involved laboratory scale, 110 $kW_{t,}$ experiments for CES's gas generator design. My second main assignment was to help with the design of a modified GE J-79 gas turbine for the CES Peaking Power Plant Module. In my third and final major assignment I assisted in the documentation and determination of life limiting factors in CES's 20 MW_t demonstration gas generator. It should also be noted that the majority of the smaller subtasks in which I participated, like attending design meetings and taking inventory, were in regards to CES's general day to day operations.

Company Background

CES's company motto is "POWER WITHOUT POLLUTION". At first this motto seems like a huckster's statement or something overtly futuristic; however, a review of the technology that CES has developed quickly shows that "POWER WITHOUT POLLUTION" is a valid and currently viable statement. To produce clean power CES has modified existing aerospace technology to create a high-energy gas generation system [1]. The gas generation system, also known as the Gas Generator (GG), burns oxygen and various synthetic fuels derived from biomass or coal, along with pure water, to produce a high-energy gas, which is mainly comprised of steam and carbon dioxide (CO_2). Of course CO_2 is still a major pollutant; thus, the GG alone is not the entire key to "POWER WITHOUT POLLUTION". But after passing the GG's high-energy gas through multi-stage turbines, which drive a generator to produce electricity, the final step in the CES power system does complete the promise of "POWER WITHOUT POLLUTION" by separating gaseous CO_2 from liquid water in a condenser. It is then that the water can be recycled back into the power system and the gaseous CO_2 can be processed into marketable CO_2 or sequestered in earth strata; therefore, completing the reality of "POWER WITHOUT POLLUTION" [1].

Energy Innovations Small Grant Project

The Energy Innovations Small Grant (EISG) project, like all of the other ongoing projects at CES, revolves around the company's revolutionary gas generation system. Since the CES GG is designed to run on oxygen and almost any clean, light hydrocarbon fuel [2] it is pertinent to understand how running various fuels can affect the performance of the GG. To achieve some insight to how various fuels may affect operating performance, as well as emissions, a fully functioning laboratory scale of CES's 20 MW_t demonstration GG was constructed, Figure 1. The laboratory scale GG was designed for 110 kW_t, and it has an inside barrel diameter of 5/8", compared to an inside barrel diameter of 4" for the 20 MW_t design.

Figure 1. CES Laboratory Scale GG, 110 kW_t

During my assignment to the EISG project the test matrix for the fuels study stated that the fuels to be studied were pure methane and high CO_2 concentration landfill gas. It is worth noting that due to the numerous types of fuels planned for study that a mixing station is used, as opposed to the use of each individual fuel. The mixing station works by taking all of the constituents of any given fuel and combines them to create the correct fuel composition, which intern allows for simple and efficient changes in the types of fuel that are to be studied and can also provide consistent fuel composition.

The study of each type of fuel involved the collection of both performance and emissions data. Performance data, which included temperatures, pressures, and flow rates, was obtained via the GG's control system. This sophisticated control system was designed to run the GG system and prevent it from becoming damaged due to excessive operating conditions; however, this system also provides critical real time information on the status of the GG, and can be used to record various data sets for performance analysis. A quadrapole mass spectrometer and a gas analyzer were used to obtain the emissions data, where a small exhaust gas sample line transported the exhaust gas from the GG to the gas analyzer or mass spectrometer. My job then mainly entailed helping with the setup of each experiment and recording and reducing both performance and emissions data.

Peaking Power Plant Module

For my second assignment I was placed on the Peaking Power Plant project, which involved the design of the Peaking Power Plant Module (P^3M). The Peaking Power Plant project, like the EISG project, is based on CES's GG. Yet, the focus of the Peaking Power Plant project is not based solely on the performance of the GG, but on how effectively the GG and other mechanical systems can be combined in order to create a clean and efficient peaking power plant,

Figure 2. Where the P^3M is the set of mechanical systems that comprises the heart of CES's Peaking Power Plant design, which include CES's GG, electrical generators, and CES's modified GE J-79 gas turbine.

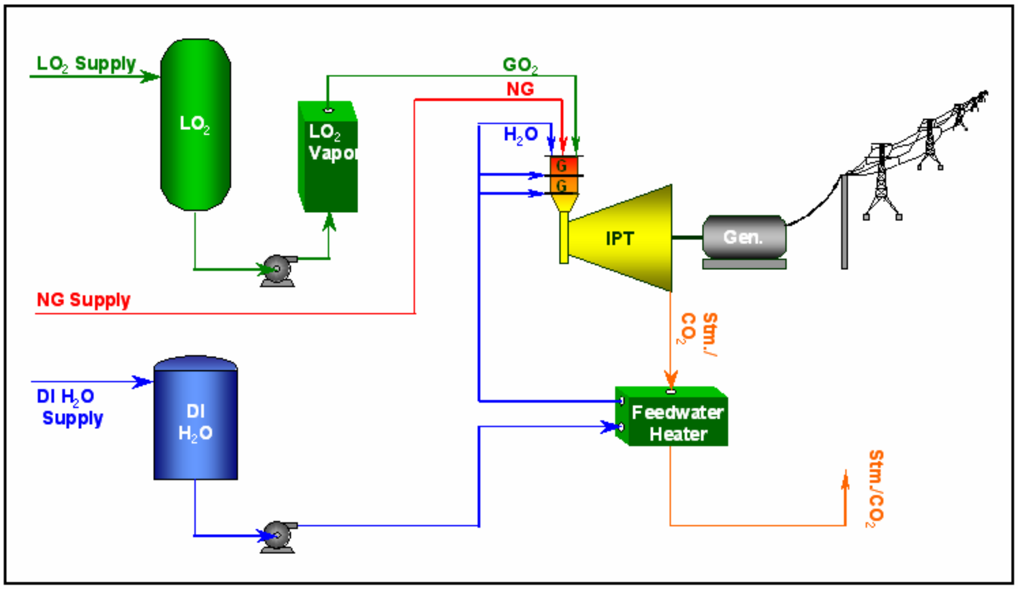

Figure 2. CES Peaking Power Plant Layout

The goal of the Peaking Power Plant project is to produce 38 MW_e of clean peaking power. In order to accomplish this the P^3M employs CES's revolutionary GG, which produces a high-energy gas comprised mainly of CO_2 and steam, to power CES's modified GE J-79 gas turbine. CES's modified GE J-79 gas turbine is not inherent to producing clean energy, but it is well suited to handle the high-temperature, high-energy gas that the CES GG produces. This ability to use existing hardware, with few modifications, helps to ensure that the peaking power plant produces green energy economically; thus, making the modified GE J-79 gas turbine crucially to the production of clean energy.

Economics, as well as clean energy, are both vital components of "POWER WITHOUT POLLUTION". This is why it is imperative that existing technology, such as the GE J-79 gas turbine, can be employed to help minimize the cost of developing a clean peaking power plant, which could become prohibitively costly if newly developed technology is used in abundance. To use the GE J-79 gas turbine as a land based power generation system several minor modifications had to be made, since the system was originally intended to be used in aircraft applications under operating conditions different than those required by the P^3M.

Therefore, during my time on the P^3M project I assisted with the design of a new labyrinth seal and the turbines secondary air requirements. A new labyrinth seal for the modified GE J-79 gas turbine was required, due to the removal of the original compressor, combustion section, and some transition ducting. The new labyrinth seal was then designed mainly to assist with achieving a desirable thrust balance, opposed to being used to prevent inter-stage leakage. To design a new labyrinth seal I helped to determine the required size of the seal based on leakage through the seal, how it affected the thrust balance, and the stresses in the seal. Removal of the original compressor also required a new analysis of the secondary flow requirements, since the original compressor is what supplied air to each of the gas turbine's bearing housings. This meant that the amount of air required to maintain the design pressure in each of the bearing housings needed to be determined, while ensuring that the air lost through each bearing housing's labyrinth seals was accounted for.

Life Limiting Factors

My final task was to assist with the life limiting factors project. This project, like the EISG project, focused on the performance of CES's GG. However, the focus of the life limiting factors project was on CES's 20 MW_t demonstration GG design, Figure 3, where as the EISG project focused on a 110 kW_t laboratory scale GG. The life limiting factors project also differed from the EISG project by the fact that it focused on the wear and tear of the GG over an extended period of time, and did not simply focus on how the GG performed under certain operating conditions for a small finite amount of time.

Figure 3. CES Demonstration GG, 170 MW_t

A need to study life limiting factors in CES's 20 MW_t GG arose after signs of clear degradation started to appear after 1000 plus operating hours. This degradation immediately raised cause for concern, since understanding why the degradation started to occur could show if there was a design flaw. A cause and effect analysis was then employed in order to help determine the cause of the degradation. The use of a cause and effect analysis could reveal what caused or led to the degradation; however, to perform such an analysis several groups of information needed to be gathered, sorted through, and organized into a viable format. Thus, it was my job to help with obtaining visual inspection records of the GG, written reports on the GG, and data logged during the GG's operation. After all of the data was obtained I then had to organize it into the forms of timelines and charts, so it could be used in the cause and effect analysis.

Conclusion

During my time at CES I was exposed to the three aforementioned main projects, as well as several other subtasks. Being exposed to so many different areas dramatically increased my learning experience and made my time at CES extremely enjoyable. I was not only able to work on and learn more about turbines and their design, but I was also able to gain a broader understanding of power generation. This exposure has definitely fueled my desire to continue on the path of learning more about turbines and their various applications, and to also work towards obtaining a career in the turbine industry.

References

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2. Anderson, Roger and Pronske, Keith. "CES Gas Generator Plant: a new kind of aeroderivative". Modern Power Systems. May 2006. Retrieved 4 Aug. 2006. http://www.cleanenergysystems.com/2005/press_documents/p20_27_mps_may06_cesi.pdf.