CAES: Combined Compressed Air Energy Storage

Restated Project Scope & Project Plan

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Project Scope

Project Statement

The problem this project will address will be storing surplus wind energy by using wind turbines to compress air at the highest efficiency possible. The compressed air will be stored in a pressure vessel and its later use will be defined for the most efficient means achievable.

Objective

The focus of this project is to identify the need for coupling wind turbines with Compressed Air Energy Storage (CAES) systems. We will design a system driven by a low speed wind turbine that directly converts mechanical energy into compressed air that is then stored and used when desired. Analysis will be done on the system performance, efficiency and energy balance. This will be done while keeping the cost and scalability of the system at a minimum while keeping efficiency high. Once the system has been designed the components will be recommended to our sponsors who will construct the system and test the systems operating efficiency.

Justification/Background

With the current energy crisis at hand there has been a lot of discussion on renewable energy and how to harvest energy efficiently. Among the most popular and most talked about forms of renewable energy are Solar and Wind Energy. Both have advantages and disadvantages that make harvesting their energy a hassle. Solar is often not reliable enough during daytime due to cloud cover and weather. The advantage is that solar panels can be placed almost anywhere there is sunlight without a dramatic effect on the aesthetics of the rest of the environment around it. Wind energy, on the other hand, produces more electricity which is better for production and, if conditions warrant, can run even when the sun is not shining.

Wind energy does require more land usage, and often times a new structure in the environment must be created. Often when there is enough wind to be harvested for energy, the electricity produced is not needed due to off peak hours. This is where storing the energy becomes crucial. There are various forms of storing energy which include, but not limited to, batteries, flywheels, capacitors, springs, and compressed air. This project is focused on compressed air.

Compressed air has a very broad range of uses where the other storage types are seemingly limited. Compressed air is used in machine shops, chemical plants, power plants, paper mills, pharmaceuticals, drilling and construction as well as many more industries. There is surely a reliable and continuous market for compressed air.

This is where the Compressed Air Energy Storage (CAES) system has attained most of its attention. However, compressing air to a higher pressure is often times one of the least efficient processes in engineering. The efficiency can be made better or worse by scaling the dimensions of the compressor and pressure vessel. CAES can be used for power plants to increase the efficiency of existing gas turbines by supplying the compressed air. Or CAES can be used by a company that is currently using electricity to compress its air and use wind turbines to compress the air instead. This in turn will reduce the company's power usage.

Current CAES systems use abandoned salt mines or natural caverns to store the compressed air. This is done at the only CAES plant in the United States. The methods of compression vary. In the Alabama plant, they use gas turbines to compress the air into the cavern during off peak hours. However, our system will be powered by wind turbines.

Methodology

Previous Work

In order to create a compressed air energy storage system we first had to research previously designed combined compressed air energy storage systems. From this research, we found that the typical method of using the compressed air to increase the efficiency of a gas turbine would be ineffective at the scale of this design project. Therefore, we conducted research on alternative compressed air generation types which lead to the decision to use a rotary air motor to generate mechanical energy from the air. This research of air motors was conducted simultaneously with research of compressor types that would fulfill the requirements inherent within the design. Once several compressors had been researched, it was decided that a twin rotary screw compressor is ideal for this application.

Next, stress calculations were performed on the pressure vessel provided by our sponsors to determine the maximum pressure that can be stored. Subsequently, a compressor and air motor were selected to provide the highest efficiency possible. The efficiency of the system was calculated based on a constant power input to the compressor from a generator powered from the mechanical energy of the wind turbine. The pressure vessel fill time was calculated and used to determine the amount of power produced by the air motor, as well as the duration of the air motors operation. This calculation was also based on the assumption that the air motor receives a constant volumetric air flow.

Additionally, the efficiency calculation was constrained so that the compressor and air motor were not operating simultaneously. Initially, the storage vessel would be filled using energy supplied from the wind turbine. Then the air would be removed to drive the air motor during high energy demands.

Work to be completed

In order to design an effective compressed air energy storage system, actual wind data to calculate the variable power output of the wind turbine is required. Due to the fluctuations of the wind speeds, the power output from the turbine will not be constant. Our solution is to first mechanically drive the compressor with the wind turbine. This removes the need for a power generator to operate the compressor.

Research will then need to be conducted in order to determine the correlation between the angular velocity of the rotating screws and the output volumetric flow rate from the compressor into the pressure vessel. Due to the fluctuating flow rates and outlet pressures, the calculation of the pressure in the vessel must be completed by integrating the derived pressure differential with respect to time. The pressure differential must be derived both for a case when the compressor is running only and a case when both the compressor and air motor are operating. Then the efficiencies of both cases can be compared.

Expected Results

Upon completion of this project, the result will be a CAES system that converts mechanical energy from the wind turbine to compressed air which is then stored and used in the most efficient way possible while considering cost and reliability. The system's performance will be rated based on a comparison between the differences in efficiencies of the two separate scenarios of use. First when the compressor and air motor operate simultaneously; and second, when the compressor is simply used as a means of storing surplus wind energy. Storing the air should result in losses that can be determined from this comparison. This data, along with a recommendation of the components analyzed, will be provided to our sponsors who will decide rather or not the efficiency meets their requirements. If the system is acceptable the system will then be constructed, tested and the actual efficiency of the system can be compared to the calculated efficiency.

Constraints

In designing the compressed air energy storage system several constraints must be taken into account. Time is a concern at this point due to the changes that have been made from last semesters work. This lack of time is going to require that a rigorous schedule be followed in order to design the system prior to the required completion date. The scalability of the system will be important as this device should be able to be sized up or down to allow it to be used in many different applications. Efficiency of the system is the most important constraint, as this system needs to be a viable option for renewable energy storage.