Enhanced Efficiency Turbine - A Novel Hybrid Fuel Cell Turbine

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ABSTRACT

The Enhanced Efficiency Turbine is a hybrid fuel cell and combustion turbine device providing increased electrical and propulsion efficiency while increasing the system durability. The Enhanced Efficiency Turbine comprises a reformer, a fuel cell, and a turbine.

The Enhanced Efficiency Turbine employs conventional hydrocarbon fuels, such as natural gas, gasified coal, propane, and is applicable to small, medium, and large electrical generation. It is also applicable to mobile and propulsion systems.

Keywords: hybrid, fuel cell, turbine, hybrid cycle

BACKGROUND

The Enhanced Efficiency Turbine has similarities to the existing hybrid fuel cell turbines.

The US DOE had considered the hybrid fuel cell turbine as the leading candidate for the next generation electrical power generators [1].

These prior hybrid fuel cell turbines had been targeted at stationary electrical power plants, such as central electrical power plants since the solid oxide fuel cell (SOFC) requires at least a day to reach operational temperature and to stabilize before it is operational.

The inial work in this area was done by Siemens Westinghouse and Fuel Cell Energy, Inc. beginning in 1990 time frame.

This DOE program has recently, in the 2012 time frame, been defunded mainly due to budget cutbacks.

TECHNICAL OVERVIEW

A hybrid fuel cell turbine is a system that integrates a fuel cell and a turbine in a synergetic combination providing operating characteristics and efficiencies of the combined system that exceeds that of the sum of the individual components.

A hydrocarbon fuel, such as natural gas, roughly contains half of its energy in the form of hydrogen and half in the carbon. The fuel cell device is a non-Carnot engine, which operates at higher efficiencies than a Carnot engine, such as a combustion turbine. According to the World Energy Council[2] "A hydrogen fuel cell operating at 25°C has a maximum theoretical efficiency of 83%, even though the fuel cell is extracting all the electrical energy possible. This compares to a maximum theoretical efficiency in a combustion engine at 500°C of 58% (assuming heat rejection at 50°C)."

The enhanced efficiency turbine converts half the fuel to energy through the fuel cell at the higher efficiency level. The remainder of the fuel, the CO and the carbon products from the reformer along with the steam output of the fuel cell, are fed to the combined turbine where it is combusted. The heat expended by the reformer and the steam expelled from the fuel cell is also recovered in the turbine. The net improved conversion efficiency of the combined turbine is enhanced over the prior gas turbines.

Counter intuitively, bypassing half the fuel, the carbon portion of the fuel, from the fuel cell provides increased efficiency in this new approach in comparison to the prior hybrid fuel cell approaches that oxidizes the entire fuel in the fuel cell. This counter intuitive improvements are attributed lower temperature operation of the fuel cell in the Enhanced Efficiency Turbine, which avoids the continuous detrimental degradation and operational life limitations.

The Enhanced Efficiency Turbine is a hybrid fuel cell turbine system characterized by:

1. Increased efficiency
2. Improved durability and operational life
3. Increased operational flexibility
4. Lower component cost
5. Decreased development risks verse the prior systems

The Enhanced Efficiency Turbine increases durability and operational life of the fuel cell by avoiding carbon oxidation in the fuel cell, in contrast to the prior system that oxidizes the carbon in the fuel cell. Avoiding carbon oxidation in the fuel cell eliminates high temperature operation and coking, the problematic build up residual carbon based deposits on the fuel cell electrodes [3].

This high temperature degradation and coking problems explained [4]. This is a major issue preventing the commercialization of the prior Fuel Hybrid Cycle approaches is avoided here.

The elimination of carbon oxidation in the fuel cell allows lower temperature fuel cell operation is a major benefit to the overall system performance and costs since the durability of the fuel cell is critical and currently accounts for two thirds of the cost of the power plant.

The key differences in this new approach are that reformed hydrocarbon is first separated into two individual streams, a carbon stream and a hydrogen stream. The carbon stream is fed into a combined turbine for combustion and the hydrogen stream is fed into the fuel cell for oxidation. The exhaust steam from the fuel cell is also fed to the turbine.
This approach avoids sending the carbon monoxide to the fuel cell that requires high temperature operation in the fuel cell. This not only increases the fuel cell life but also allows the use of other types of fuel cells, such as PEM fuel cells, operating at lower temperatures.

The system uses a combined turbine which combusts the carbon monoxide, the reformat products, with the steam from the fuel cell. The turbine in this approach produces more energy than the turbine subsystem over the prior system that only generates power by blowing through the hot gasses.

A working Enhanced Efficiency Turbine device could comprise commercially off the shelf subsystems such as a reformer, hydrogen carbon separators, a combustion turbine and a fuel cell with the necessary controls and plumbing.

CONCLUSION

The Enhanced Efficiency Turbine is a new hybrid fuel cell and combustion turbine device applicable to electrical and propulsion generation efficiency while increasing the system durability.

This new system avoids the high temperature failure mechanisms of the SOFC that have plagued the usable life of the previous systems. It also enables the flexibility to use a variety of other fuel cell types such as PEM fuel cells

REFERENCES

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