Hybrid Power Generation System for Powering Zero Energy Building

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Abstract: - In this paper, a hybrid captive green power generation system is discussed, which would be a self-sustainable power generation technique for powering of zero energy building. Two green technologies will make up this system to generate the power, viz. reconfigured building integrated photovoltaics and hybrid fuel cell system comprising of gas turbine and high temperature fuel cell. The choice of fuel cell technology and scheme for efficient power conditioning has been modeled for this particular application.

Key-Words: - ZEB; RBIPV; HCGPGS; HTFC; LTFC; SSPCU

1 Introduction

The major concern today is the rapid depletion of fossil fuel stock because of tremendous rise in the demand for power requirements by various establishments. As a result of this, the trend has moved to adapt Green Sources of power generation.
There are different types of sources of Green energy such as Solar Photovoltaics (SPV), Fuel Cell (FC), Wind Energy, and Tidal Energy. Out of these technologies, SPV and FC can be incorporated in any establishment easily.
Using these technologies, a Zero Energy Building (ZEB) can be build. Thus, a scheme to a hybrid captive green power generation system (HCGPGS) for this ZEB power requirements is proposed. A typical power requirement of any establishments throughout the day can be as shown in Fig. 1. This ZEB would be self-sustainable for power generation.

2 Objectives of the paper

The main objectives of this investigation are

1. Have a ZEB which self-sustainable towards power generation to address the power requirements of that establishment without taking power from the existing power grid
2. Use of HCGPGS which would be generated on-site
3. This hybrid green power will come from the Reconfigured Building Integrated Solar Photovoltaic (RBIPV), Hybrid Fuel Cell comprising a combination of Gas turbine and Fuel Cell operating by use of multi fuel option
4. The response of this HCGPGS to meet the transient requirements of ZEB

3 Power Requirements of any establishment

The typical power requirements of any establishment is shown in Fig. 1.

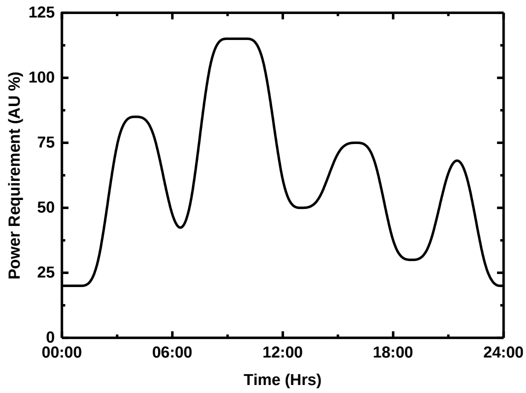

Fig. 1 Power usage in a typical establishment

As seen from Fig. 1, the power requirements of any establishments vary transiently from time to time in the span of the day. These requirements are in few MW/hr.

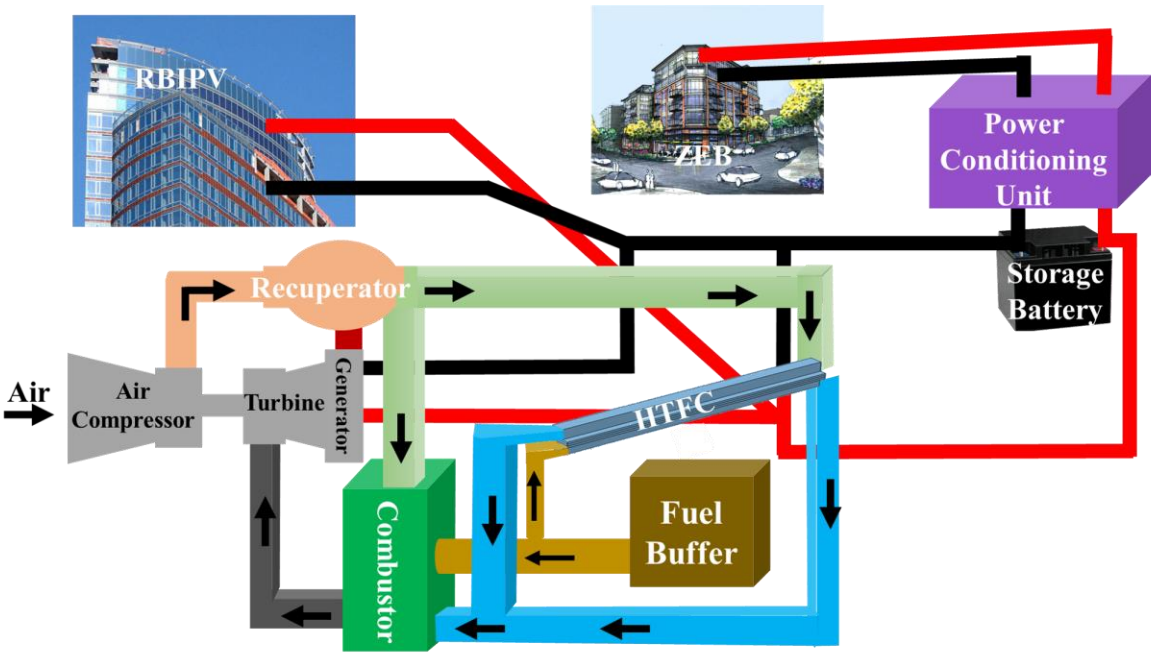

Fig. 2 Schematic of the proposed HCGPGS

2 System Configuration

The schematic of the system we are proposing as a Hybrid Captive Green Power Generation System (HCGPGS) for the ZEB is shown in Fig. 2.

The components of the HCGPGS are:

i. RBIPV
ii. Multi Fuel option driven Hybrid Fuel Cell System (MFODFCS): -
   - Fuel Cell
   - Gas Turbine
iii. Smart Storage and Power Conditioning Unit (SSPCU)
iv. ZEB (load)

3.1 *RBIPV*

The SPV modules are mounted on motorized towers so that they are able to track the sun throughout the day.

Fig. 3 (a) Traditional SPV rooftop installations, (b) RBIPV installation scheme using flexible PV module

These modules trap the solar energy to produce electricity and being eco-friendly.

These occupy large areas and need clear area so that there is no shading effect on the modules as it would affect the performance. Also, they are bulky and need special structural modifications so as to set them up over a rooftop as shown in Fig. 3 (a).

Instead of this a RBIPV [1 – 3] can be incorporated in any structure by using flexible PV modules so that they can be covered over the contoured rooftops as well as shown in Fig. 3 (b). These RBIPV installations range from few kW’s to MW’s.

3.2 MFODFCS

The MFODFCS is a combination of gas turbine generator connected to a Fuel Cell which helps in achieving higher efficiencies [4 – 6]. Using COMSOL Multiphysics®, efficiency comparison between the two major fuel cell technologies, viz. Low Temperature Fuel Cell (LTFC) [7 - 9] and High Temperature Fuel Cell (HTFC) [10 - 12] have been simulated as shown in Fig. 4.

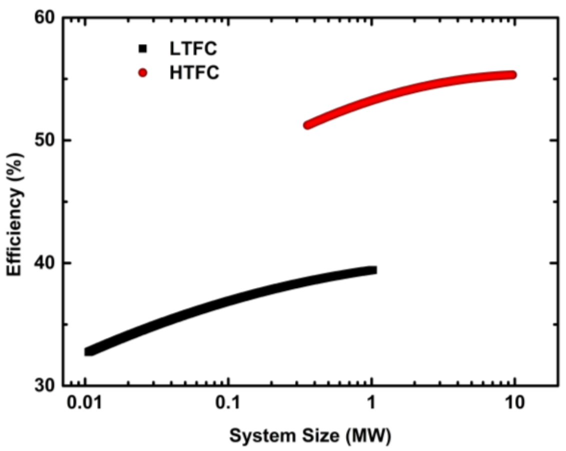

Fig. 4 Higher efficiency is seen in HTFC

As seen from Fig. 4, a second order dependence is observed for both LTFC and HTFC as a function of efficiency to the system size. The change is observed due to the uniformity of ion transport across the electrolyte area [13] and also due to the stacking of multiple cells to boost the performance. The HTFC technology has a higher efficiency and thus suitable for having a ZEB as seen from Fig. 4.

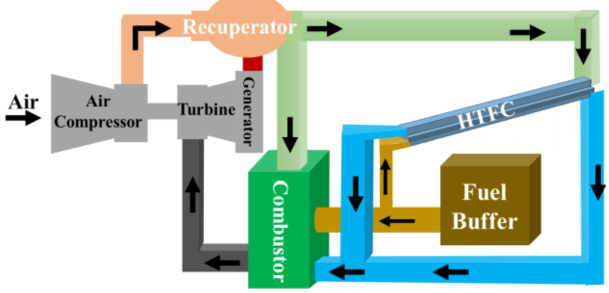

Fig. 5 Schematic of a MFODFCS

The schematic of the proposed MFODFCS is shown in Fig. 5. The fuel options used for running this system are (i) Hydrogen (ii) Landfill Methane, (iii) CNG, and (iv) LPG. These fuels are easily available and can be used as per the availability. HTFC performance dependence is modelled and explained in [9, 10, 12, 14]. The HTFC will be a stack of HTFC's connected in a series and parallel combination to deliver the desired power requirements. The schematic of this combinational connection is shown in Fig. 6. These stacks range from few tens of kW's to hundreds of MW's.

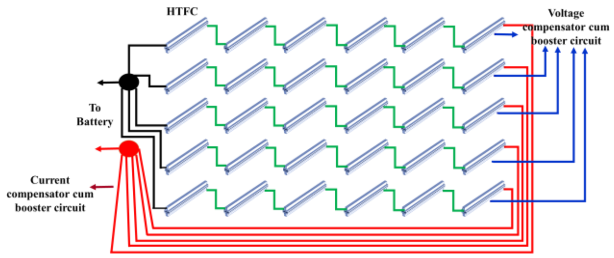

Fig. 6 Schematic of a combinational connection of HTFC stack

Recuperator uses the exhaust of this system to provide the necessary heat for the HTFC stack to function.

3.3 SSPCU

The power generated by HCGPGS is stored in fast discharge batteries by conditioning to meet the power rating of the ZEB.

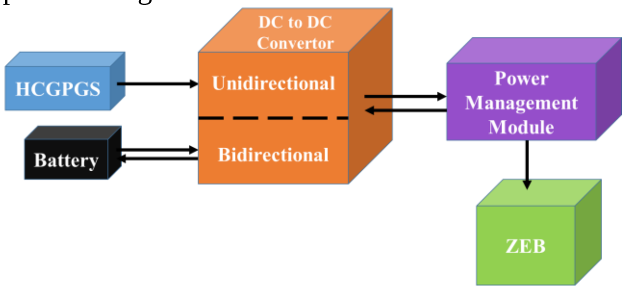

Fig. 7 Schematic of the HPS

Due to the unstable environmental conditions, the HCGPGS terminal voltage varies, therefore HCGPGS voltage needs to be regulated, and boosted with power converters. Energy storage units (ESU), such as a fast discharge battery are used. The schematic of HCGPGS fed power source (HPS) for testing dynamic load profiles (Fig. 7). HPS consists of a HCGPGS, fast discharge battery, power converter, power controller and HCGPGS controller. The power controller will generate a reference signal for flow control based on the load power and HCGPGS current requirement.

The ESU is connected to the dc-link capacitor in parallel through the bidirectional converter for maximum HCGPGS utilization as shown in Fig. 8.

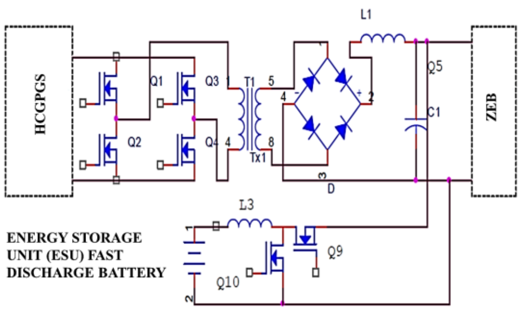

Fig. 8 Power converter configuration with bidirectional converter for HCGPGS - Battery interface

The response to the load requirement of HCGPGS–ESU system has been modeled and is shown in Fig. 9. As seen from Fig. 9, the ESU gets charged by the HCGPGS when the power requirement by the ZEB is low and the HCGPGS slowly meets the full power requirement when the transient power requirement arises.

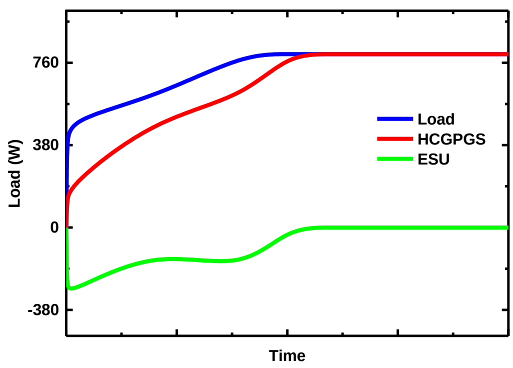

Fig. 9 HGPGS – ESU response to the transient power requirements of the GDC (Load)

4 Conclusion

Thus, a HCGPGS is proposed which would be able to generate self-sustainable power to meet the power requirements of a ZEB. The fuel cell technology is modeled for this application with multi fuel option so as to be functional as per the fuel availability alongwith the modeling of the response of the power conditioning unit. Thus, the power system will be a captive power generation facility and will be locally generated near the ZEB. This HCGPGS can be scaled from few kW to MW as per the requirement of ZEB.

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