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Optimization of a Solar Photovoltaic, Biomass Gasifier and Fuel Cell Hybrid System

A. singh* and P. Baredar

EnergyCentre, Maulana Azad National institute of Technology, Bhopal, India

P A P E R I N F O

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A B S T R A C T

In this paper sun situated photovoltaic (PV), fuel cell, biomass gasifier generator set, battery reinforcement and force molding unit have mimicked and advanced for an instructive establishment, Energy Center, Maulana Azad National Institute of Technology, Bhopal in the Indian condition of Madhya Pradesh. The zone of the study range on the aide arranged of 23° 12' N scope and 77°24'E longitude. In this structure, the key wellspring of force is sun based sunlight based photovoltaic framework and biomass gasifier generator set while fuel cell and batteries were used as fortification supply. Hybrid optimization model for electric renewable test system has been used to reproduce off the framework and it checks the particular and money related criteria of this cross breed vitality framework. The execution of each section of this structure is analyzed in conclusion. The sensitivity examination was performed to upgrade the blend system at different conditions. In a perspective of the entertainment result, it is found that the expense of vitality of a biomass gasifier generator set, sunlight based on PV and power device hybrid vitality framework was observed to be 15.064 Rs/kWh.

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INTRODUCTION

In a hybrid energy system various electrical energy generators and electrical energy storing device are consolidated together to take care of the electrical power demand of remote and country zone or even an entire group [1]. Fig ure1 shows that standalone PV generators, biomass gasifier, little hydro plants, Fuel cell, wind turbine and others wellsprings of electrical energy can be added as expected to take care of the electrical power demand in a way different determines. The motivation behind this paper is the recreation displaying and streamlining of a sunlight based photovoltaic, biomass gasifier generator set and fuel cell hybrid energy framework [2]. It couples a sunlight based photovoltaic generator, biomass gasifier generator set energy component and fuel cell unit to give diverse framework topologies. This framework is proposed to be an earth amicable arrangement since it tries to boost the utilization of a renewable energy source. These developed systems are also considered as clean, pollution free and environmental friendly processes. Photovoltaic generators which straightforwardly change over sun based radiation into power have a considerable measure of critically favorable position, for example, being in modest and contamination free, quiet with no turning part and with size autonomous electric transformation productivity. From an operation perspective, a PV power era encounters huge varieties in its yield power because of irregular climate conditions. One strategy to conquer this issue is to incorporate the photovoltaic framework with another force source, for example, biomass gasifier generator set, fuel cell, wind power, battery go down and the diesel goes down generator along these lines, as to guarantee a ceaseless 24 hour supply. National Renewable Energy Laboratory's (NREL) hybrid optimization model for electric renewable (HOMER) simulator has been utilized to complete the present study [3]. HOMER performs arelative financial examination on a disseminated era power frameworks. Inputs to HOMER will play out an hourly recreation of each conceivable blend of segments entered and rank the frameworks as per client determined criteria, for example, the expense of energy (COE, RS/kWh) or capital expenses.

Present renewable energy scenario in india

India is a nation with more than 1.2 billion populations representing more than 17% of the world's populace. It is

* Corresponding author: Anand singh
E-mail: anand24883singh@gmail.com

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the seventh biggest nation on the planet with the aggregate area territory of 3,287,263 km^2. India measures 3214 km from north to south and 2993 km from east to

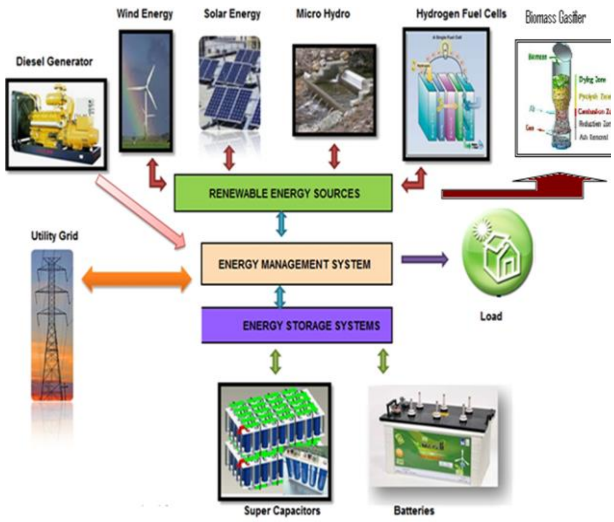

Figure 1. Hybrid renewable energy system [4]

west [5]. It has an area outskirts of 15,200 km and a coastline of 7,517 km. India has 28 states and 7 union domains. The power utilization per capita in India is only 566 kWh. India turned into the world's third-biggest maker of power in the year 2015 with 4.8% worldwide offer in power era surpassing Japan and Russia. However, she is still a power shortage nation. Regardless of gigantic development in power generation, the country keeps on confronting both energy and top deficiency [6]. Amid the year 2014–15, there is an energy, lack of 5.1% and top lack of 2.0%. Power lack is not by any means the only issue. Its spread is a similarly major issue. Previously, the choice of an energy asset for power era was ruled by finding the slightest costly power creating aplant. Albeit such a methodology is crucial, there is developing worry about different parts of force are such age, social, natural and mechanical advantages and results of the energy source choice [5]. Coal has the most extreme a worldwide temperature alteration potential took after by natural gas and others. Further, it should be re-underscored that in India, as most creating nations, the expense of delivering power is of foremost concern while making arrangements for the sort of plant to be introduced and authorized and all the more so with an inexhaustible supply of coal. Nonetheless, over the long haul on the off chance that we produce the results of the poisons on human wellbeing and environment and expense and endeavors expected to enhance or modify the way of debasement, the underlying higher expense of utilizing renewable assets for delivering energy may not be too huge. A high level of alert is additionally required as rising economies like India may not at present have money related assets to jump specifically to cleaner components of energy. Since an earth-wide temperature boost is a global marvel and it has no limits. There is a dire requirement for the exchange of innovation and improvement of suitable money related instruments from built up the world to countries who are as yet attempting to locate their legitimate spots. No contention is expected to comprehend that the world is today confronting the issue of an earth-wide temperature boost because of quick industrialization and urbanization took after by the Western world. Regarding per capita value India is 145th on the planet with an arrival of 1.25 ton CO_2 for per annum [7]. The essential hotspots for the generation of power in this nation are coal, fuel, gas and hydro power. Be that as it may, the assets like coal, gas or fuel is not boundless and won't have the capacity to provide food the force prerequisite for mass individuals following a couple of years. This is the reason now-a-days India is working for the generation of power from renewable energy sources of nature like a wind mill, sun based power, tidal power, biomass and waste material, Fuel Cell, geothermal energy and so forth. India uses to power from renewable energy sources diminishes the issue of an earth-wide temperature boost power from renewable energy sources diminishes the issue of an earth-wide temperature boost.

Proposed hybrid energy system

A Solar photovoltaic energy source should be hybrid with other energy sources, whether used in either a stand-alone or grid-connected mode. Stand-alone energy systems are very popular, especially in remote sites. Figure 2 shows that system under study in this paper is the dynamic modeling of a solar photovoltaic and proton exchange membrane (PEM) fuel cell hybrid energy system, which is constituted of a photovoltaic generator, fuel cell, biomass gasifier generator set, battery and power conditioning unit. The development of appropriate simulation tools will help in dealing with modeling, simulation, and design and energy management of the system under study [8]. The object of present study is to reach a design that optimizes the operation of a solar photovoltaic, biomass gasifier generator set and fuel cell hybrid energy system.

Hybrid energy system costs analysis

Hybrid energy System made up of the solar photovoltaic fuel cell, biomass gasifier, and battery storage. The optimization of the size and cost of hybrid energy system is very important and leads to a good ratio between system cost and performances.

Solar Photovoltaic System

Sunlight can be directly converted into electric energy by photovoltaic (PV) panels [9]. The current output of a PV panels a function of voltage and as a function of solar radiation. As solar radiation increases, so do both the current and the voltage of the panel [10]. The panel's power output can be found by multiplying the current and the voltage [11].

A 1 kW solar PV energy system's installation and replacement costs are taken approximately as Rs.150,000/- and Rs.100,000. The life time of the solar PV arrays are taken as 20 years and no tracking system is included in the solar PV.

Fuel cell

A fuel cell is an electrochemical gadget that converts chemical energy directly into electrical power. Like a battery, an energy component comprises of a couple of terminals and an electrolyte. A fuel cell comprises a polymer electrolyte film sandwiched between two terminals (anode and cathode). In the electrolyte, no one but particles can exit and electrons are not permitted to go through. In this way, the stream of electrons needs a way to an outside circuit from the anode to the cathode to create power on account of a potential distinction between the anode and cathode. [12].

The cost of PEM fuel cell varies widely depending on scale, power electronics requirements, and reformer requirements. In this paper, we assumed fuel cell capital cost 200,000 Rs/kW, Replacement cost 150,000 Rs/kW size varied for 0 to 5 kW. This study assumed fuel cell life time 1500 hours.

Biomass gasifier

The creation of generator gas (maker gas) called gasification, is the fractional burning of strong fuel (biomass) and happens at temperatures of around 1000^0C. The reactor is known as a gasifier. The burning items from complete ignition of biomass, for the most part, contain nitrogen, water vapor, carbon dioxide and excess of oxygen. However in gasification where there is an overflow of strong fuel (inadequate burning) the results of ignition are flammable gasses like carbon monoxide (CO), Hydrogen (H_2) and hints of Methane and non-helpful items like tar and tidy [13]. The power production in the small-scale biomass gasification plants is almost totally made via internal combustion engines (ICE). In this paper we expected energy unit capital cost 96,000 Rs/kW, replacement cost 5.

In the cost-advancement strategy, HOMER reproduces every framework design in the pursuit space and shows the conceivable ones in an outline, sorted by net present cost [14]. Hence, it shows a subset of these overall optimization results by displaying only the least-cost configuration within each system category or type [15]. The cost of the hybrid energy system (C_{HES}) becomes the sum of the cost of its individual components i.e. solar PV system cost (C_{SPV}), fuel cell cost (C_{FC}), biomass gasifier cost (C_{BG}), battery cost (C_{BAT}), electrolyzer cost (C_{ELECTO}), power converter cost (C_{PCON}) and hydrogen tank cost (C_{HTANK}).

$$C_{HES} = C_{SPV} + C_{FC} + C_{BG} + C_{BAT} + C_{ELECTO} + C_{PCON} + C_{HTANK} \quad (1)$$

Cost of each component of hybrid energy system,

$$C_i = N_i \times [CapC_i + (\mathrm{Re}\,C_i + NR_i) + OMC_i] \quad (2)$$

where, $i =$ Component of the hybrid energy system (Solar PV/fuel cell/Biomass gasifier/Power converter/Electrolyzer/Hydrogen tank), N_i= Number/Size of hybrid energy system component , Cap $C_i =$ Capital cost hybrid energy system component,$ReC_i =$ Replacement cost hybrid energy system component,$NR_i =$ Number of replacements, $OMC_i =$ Operation and maintenance cost hybrid energy system component .HOMER first evaluates the specialized achievability of the framework and whether it can take care of the load demand. Second, it appraises the aggregate net present cost (NPC) of the framework, which is the life-cycle expense of the framework, including the initial set-up costs (IC), part replacement costs (RC), operation and maintenance costs (OM), fuel costs (FC), and the acquiring power costs (PC) from the network. HOMER figures NPC by the accompanying equation [16].

Load demands proposed area

The selected proposed area of an educational institute, Energy Centre, Maulana Azad National Institute of Technology (MANIT), Bhopal in the Indian state of Madhya Pradesh in Figure 2 [17]. The location of the study area on the map located off 23° 12' N latitude and 77°24'E longitude. Energy centre MANIT Bhopal the basic load is required to use electrical appliances like tube light, ceiling fan, experiment setup, computer, and machinery [18]. The energy load demands in the morning and night, the hour is small. Load demand to 8 hours from 9:00 to 5:00 approximant high as compared morning and night hour. In this study, 5 kW has been considered to scale peak load.

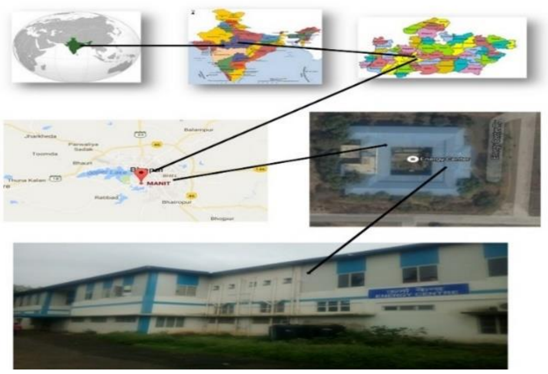

Figure 2. Location of study area Maulana Azad National institute of Technology, Bhopal in the Indian state of Madhya Pradesh

Simulation Model

The simulation model has been designed HOMER Pro software and consists of a biomass gasifier, solar, fuel cell, battery and electrolyzes[15]. There are sources of energy in this system: solar PV, biomass gasifier, and fuel cell. A fuel cell is operated when there is a lack of power generated by the solar PV system and biomass gasifier. Hydrogen tank for the utilization by the fuel cell. Although the battery is an energy storage device, it acts as a source of energy when the load demands additional energy which cannot be satisfied by the two main sources. The system architecture of this hybrid energy system is shown in Figure 3.

Figure 3. HOMER simulation model of solar PV, biomass gasifier generator set, and fuel cell hybrid energy system

Simulation Results

As per the above-given input parameters and constraints, simulation has been carried out using HOMER pro. The economic expected results of the same are given in Figures 4 and 5. The selected options for the component sizing, obtained after simulation, based on the cost of energy and unmet load. It is observed that the size of the sources required increases and the cost of energy also increases. Hence for the proposed system, the optimal sizing of the components is selected for an unmet electrical load of 0 %, capacity shortage 0 % and excess of electricity 36 kWh/year with a cost of energy of 15.064 Rs/kWh and total net present cost Rs.5,189,003. The Main energy source solar photovoltaic capacity has been allowed to vary 0 to 5 kW. Fuel cell power has been considered to change from 0 to 5 kW. Biomass gasifier generator sets 5 KW. The average consumption of the AC primary load is 26645 kWh per year. Simulation results of the same are given in Figures 6 to 11. The monthly average electricity production of the solar PV system, fuel cell, and biomass gasifier is shown in Figure 10. It can be seen that the power production of the solar PV system is 8,481 kWh/year, fuel cell power production is 7300 kWh/year and biomass gasifier generator set power production is 13,957 kWh/year.

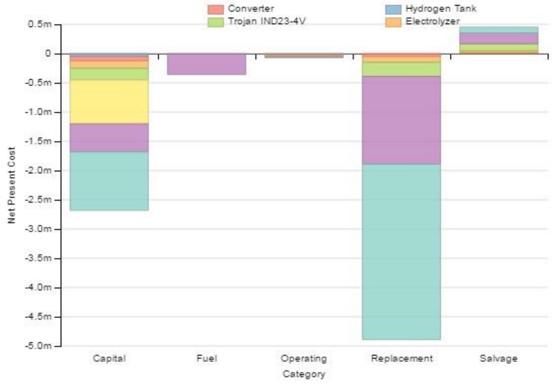

Figure 4. Annual cost analysis of HES different component

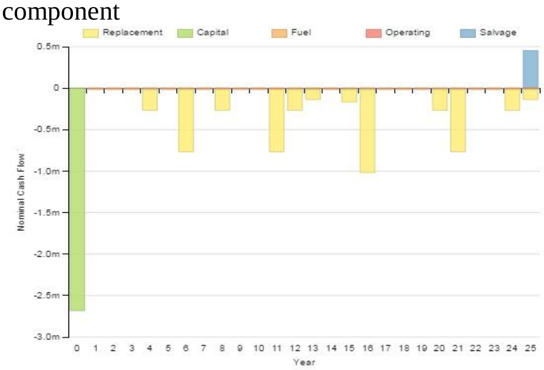

Figure 5. 25 years cost analysis of HES different component

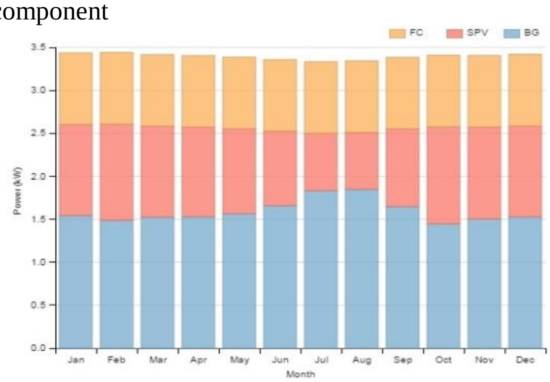

Figure 6. Monthly average power of HES different component

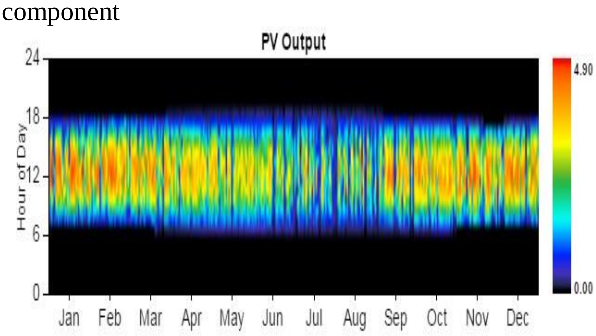

Figure 7. Monthly average power of solar PV system

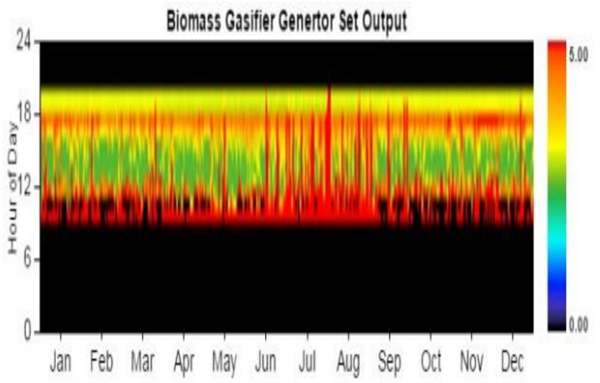

Figure 8. The monthly average power of biomass gasifier generator set

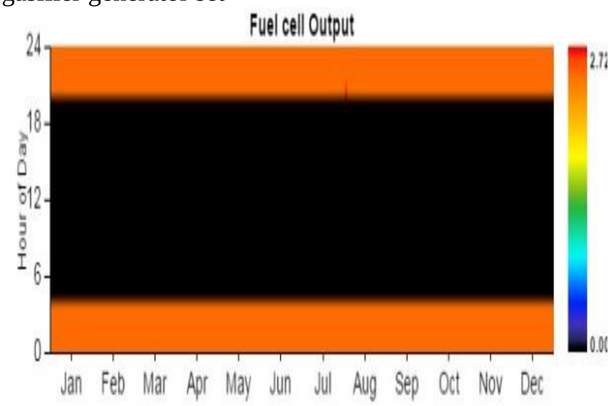

Figure 9. Monthly average power of fuel cell

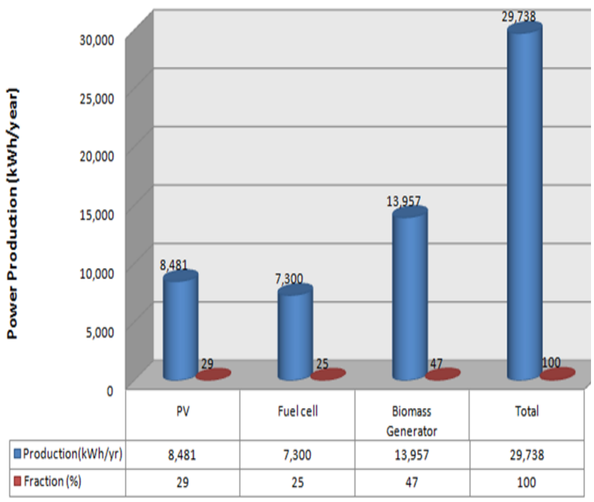

Figure10. Electrical power production sharing by solar PV, biomass gasifier generator set and fuel cell

CONCLUSION

In this paper reproduction and advancement of a biomass gasifier generator set, solar PV and fuel cell hybrid system carried out for electrical force supply at Energy Center MANIT Bhopal done utilizing HOMER software. The expense of vitality (COE) of a biomass gasifier generator set, solar PV and fuel cell crossover vitality framework have been found to be 15.064 Rs/kWh and all out net present cost Rs. 5,189,003. The abundance power in the proposed framework is observed to be 36 kWh/year

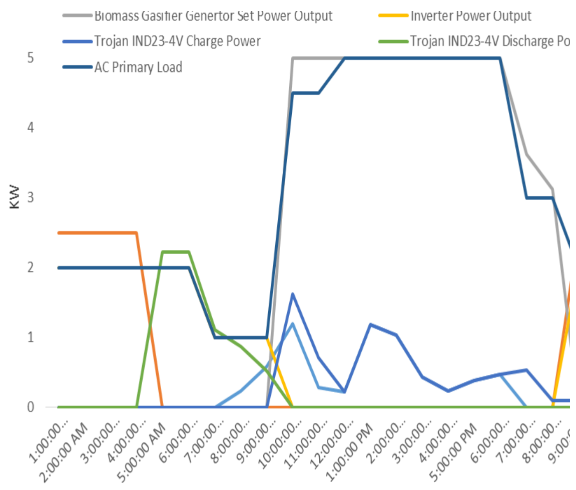

Figure 11. Power Shared by the Components of the hybrid energy system for a Day

with zero rates unmet electrical burden. The after effects of the proposed framework obviously accept that with the improved measuring of 5kW biomass gasifier generator set, 5kW sun oriented PV, 5kW fuel cell, the framework had the capacity to bolster the changing burden prerequisite in every one of the seasons with no force interference.

Acknowledgement

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.

Persian Abstract

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چکیده

در این مطالعه استفاده از انرژی های نو شامل سلول های خورشیدی، پیل سوختی، گازی سازی بیومس و ... در محل دانشگاه مولانا آزاد در بوپال هندوستان مورد بررسی قرار گرفت. نور مورد استفاده بر روی سلول های خورشیدی نور خورشید بوده است. استفاده همزمان از انواع انرژی های تجدید پذیر جهت تامین انرژی در این مطالعه مد نظر بوده است. این تحقیق نشان از آن دارد که با استفاده همزمان از انواع انرژی های تجدید پذیر می¬توان انرژی مورد نیاز یک ساختمان را با قیمتی برابر ۱۵ روپیه به ازای کیلووات ساعت تامین کرد.