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Techno-economic feasibility analysis of hydrogen fuel cell and solar photovoltaic hybrid renewable energy system for academic research building

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ABSTRACT

A hydrogen fuel cell (HFC) and solar photovoltaic (SPV) hybrid renewable energy system (HRES) for stand-alone applications is proposed. This system arrangement of a hydrogen tank, battery, and an electrolyzer are used as like the energy storage. The economic viability of using HRES power to supply the electrical load demand of academic research building located at 23°12′N latitude and 77°24′E longitudes, India is examined. The fuzzy logic program computes the optimum value of capital and replacement cost of the components, which is then utilized in HOMER pro software to calculate the optimum performance of HRES. The results shows the HFC and battery bank are the most significant modules of the HRES to meet load demand at late night and early morning hours. The AC primary load consuming 20712.63 kWh/year out of total power generation of HRES which is 24570.72 kWh/year. The excess of electricity produced by HRES is 791.7709 kWh/year with the optimized cost of energy, unmet electrical load and capacity shortage of 0%.

1. Introduction

Various components need to keep taken in estimate now act together with stand-alone hybrid renewable energy system (HRES) for the era of electricity [1]. Reliability and cost are pairs over these aspects; that is viable in conformity with ensuring up to expectation hybrid stand-alone electrical energy technology systems are generally greater reliable then much less costly than systems up to expectation count number about an alone source of strength [7]. The utilization of renewable electricity can furnish a sustainable access to electricity to customers in householder in rural area, academic institute, irrigation, food preservation, cooling and small scale industries [2]. This method combines multiple renewable power sources in imitation of extending the reliability that can't stand ensured along an odd renewable power source. The combination of various sources consisting of biomass, solar photovoltaic (SPV), wind turbine, micro-hydro plants, hydrogen fuel cell (HFC), battery, super capacitor, sources are extra tremendous as these can suppress rapid modifications of the output electricity and additionally produce greater secure power [3]. Fig. 1 indicates that SPV, biomass gasifier, HFC, micro hydro plants, wind energy and others wellsprings of electrical power can be introduced as expected to take care of the electrical energy demand in a way distinctive determines [4].

The literature noted exhibit up to expectation various studies, as good greatness methodologies, or feasibility and techno-financial analyses about SPV/HFC/Battery power structures are conducted along mathematical strategies or hybrid optimization model for multiple energy resources (HOMER) simulation software within various countries shown in Table 1. This paper object to investigate techno-economic feasibility of stand-alone hybrid HFC–SPV energy system for power to supply the electrical load demand of academic research building located at 23°12′N latitude and 77°24′E longitudes, India. Fig. 2 shows the block diagram of hydrogen fuel cell and solar photovoltaic HRES. The remainder of the paper is organized as follows. Site description and resource assessment in Section 2. Load profile for academic research building in Section 3. HRES components description Section 4. Fuzzy logic (FL) based HRES components cost analysis in Section 5. Proposed simulation model in Section 6. Results and discussion of proposed system in Section 7. Finally, the conclusion of this work is presented in Section 8.

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Nomenclature

HRES	hybrid renewable energy system
HOMER	hybrid optimization model for multiple energy resources
HFC	hydrogen fuel cell
SPV	solar photovoltaic
WT	wind turbine
DG	diesel generator
HP	hydro plant
MANIT-B	Maulana Azad National Institute of Technology, Bhopal
NASA	National Aeronautics and Space Administration
SA	stand-alone
GC	grid connected
FL	fuzzy logic
Y_{spv}	rated capacity of the solar photovoltaic array, meaning its power output under standard test conditions [kW]
f_{spv}	solar photovoltaic derating factor [%]
G_T	solar radiation incident on the Solar photovoltaic array [kW/m^2]
$G_{T,STC}$	incident radiation at standard test conditions [1 kW/m^2]
α_p	temperature coefficient of power [% °C]
T_C	solar photovoltaic cell temperature in the current time step [°C]
$T_{C,STC}$	solar photovoltaic cell temperature under standard test conditions [25 °C]
Q_{N-E}	nominal hydrogen mass flow (kg/h)
Q	hydrogen mass flow (kg/h)
A_E, B_E	coefficients of the consumption curve in kW/kg/h
E_L	total energy demand
AD	daily autonomy
DOD	battery's depth of discharge
η_{inv}	inverter efficiency
η_b	battery efficiency
V_{batt}	battery voltage (V)
R	gas constant [8.3145 J/(mol K)]
F	faraday constant [96, 485 As/mol]
z	number of moving electrons (z = 2)
E_{nerst}	nernst voltage (V)
a	charge transfer coefficient
P_{H_2}	partial pressure of hydrogen inside the stack (atm)
P_{O_2}	partial pressure of oxygen inside the stack (atm)
k	Boltzmann's constant (1.38×10^{-23} J/K)
h	Planck's constant (6.626×10^{-34} Js)
ΔG	activation energy barrier (J)
T	temperature of operation (K)
K_c	voltage constant at nominal condition
R_{int}	internal resistance (Ω)
CBT	cost of battery
CSPV	cost of solar photovoltaic
CHFC	cost of hydrogen fuel cell
CEL	cost of electrolyzer
CCON	cost of converter
NPC	net present cost
CoE	cost of energy
UEL	unmet electrical load
EE	excess energy
C_{NPC}	total net present post in $
C_{AT}	total annualized cost in $/year
CRF	capital recovery factor
i_r	interest rate in % (6.18%)
i'	nominal interest rate
f	annual inflation rate
N_{proj}	project life time in years (20 year)
$C_{A,Ca}$	annualized capital cost
$C_{A,Re}$	annualized replacement cost
$C_{A,OM}$	annualized maintenance cost
$C_{A,Fu}$	annualized fuel cost of HRES
$C_{I,Ca}$	initial capital cost of the component
C_{Re}	replacement cost of the component ($)
F_{Re}	replacement factor
SFF	sinking fund factor
S	salvage value of the component

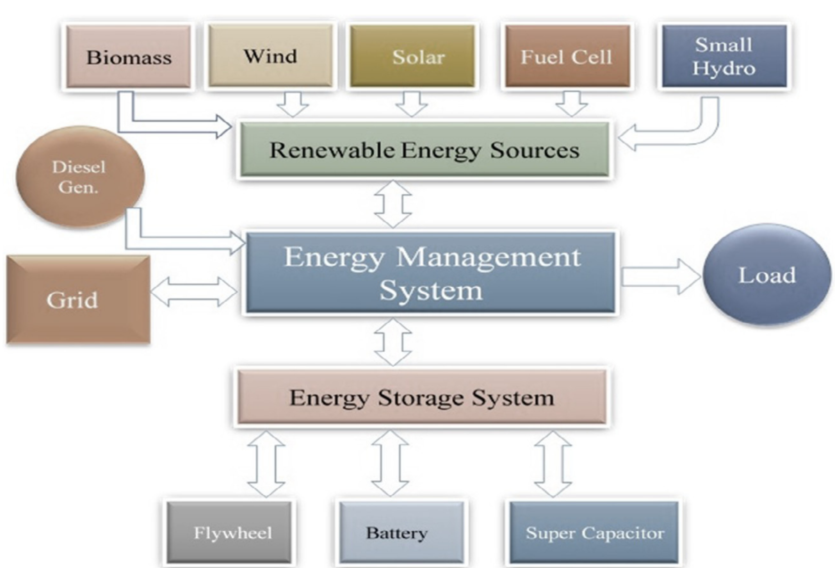

Fig. 1. Representation of hybrid renewable energy system (HRES).