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Socio-techno-economic design of hybrid renewable energy system using optimization techniques

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ABSTRACT

This paper presents the optimal hybrid power system design including various configurations of renewable energy generation. To decide the optimal configuration of parameters a new multi-objective function with six separate objectives of hybrid renewable system is presented using GA, PSO, BFPSO and TLBO optimization techniques. The different parameters namely technical (LPSP, Renewable factor), economical (COE, Penalty & Fuel consumption) and social (Job creation, HDI & PM) features are investigated as objectives simultaneously for optimal design of hybrid system. The design consideration of hybrid system using a novel PM factor, human health impacts are directly shown whereas pollutant emission is measured in the hybrid system design. Based on the minimum value of multi-objective function optimal values are decided for objective indices. For optimal configuration including various combinations of wind, PV, diesel generator, biomass and battery bank, separate cases from I to VI of hybrid system are tested. Performance of TLBO is found to be better than BFPSO, PSO and GA as per the analysis of results for individual cases. Also the case I found to be the most efficient solution among all cases.

1. Introduction

Conventional fuel is the main source of electricity generation but it produces a large amount of carbon and it's by-products in the environment. Thus harmful gases are the main concern now a day in the world which damages the greenhouse system of the environment. This problem can be reduced through the renewable energy sources such as solar, wind and biomass etc. Energy and ecological security issues are being confronted by most nations nowadays. The explosion of the human populace on the earth has brought on a consistent growth in the need for energy, especially electricity. The developing trend in energy application is 2.8% increment for each annum. But such an expanding demand for power on a worldwide scale cannot be taken care of by the current structure of energy sources [1]. The increasing cost of conventional power and environmental pollution has led to the consideration of alternative renewable sources for power generation. Thus renewable energy sources are designed as off-grid or grid connected system. Off-grid hybrid renewable energy sources (HRES) with a diesel generator and battery unit are used for electrifying far off locations. In literature optimal sizing of the off-grid system is investigated regarding lowest net present cost (NPC), cost of energy (COE), loss of power supply probability (LPSP) and maximum renewable factor (RF) [2,3]. Many studies are also reported for minimization of carbon dioxide, unmet load, penalty cost of emission, and maximization of job creation factor (JCF), human development index (HDI) [4–6]. Optimal sizing of hybrid system has been also evaluated on the basis of social parameters, technical parameters and economical parameters with multi-objective and multi-criteria in the previous studies.

In remote areas where human advancement factor is generally minimum, a key factor in lessening the poverty is access to electrical power [7,8]. According to report 2014, a large portion of the world population around 17.8% cannot access the electrical power which indicates a low human development index [9]. HDI factor is improved if the living standard of the population increases such as better use of electricity; better education, higher net earnings per capita and use of electrical appliances, new industry and jobs. The technical design has been suggested as an important factor by many authors due to its effect on the HDI [10,11]. The HDI approach depends on four key columns that must bolster any vital advancement activity to achieve what we mean by achievement:

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Nomenclature

HRES	Hybrid renewable energy sources
GA	Genetic algorithm
PSO	Particle swarm optimization
TLBO	Teaching-Learning-Based Optimization
COE	Cost of energy
LPSP	Loss of power supply probability
P_c	Emission cost
HDI	Human development index
JCF	Job creation factor
C_c	Carbon content engaged
RF	Renewable factor
PM	Particular matter
NPC	Net present cost
P_{WIND}	Power generated through the wind plant in MW
VSDG	Variable speed diesel generator
CRF	Capital recovery factor
$\eta_{inverter}$	Efficiency of the inverter
N	No. Of swarm
$f\max_{ELOAD}$	Element to increase yearly AC load in order that the maximum surplus energy
e_{SE}	Yearly surplus energy of the system in kWh/yr
n_{HUMAN}	A number of humans which consume the generated power through the hybrid system
JC_{PV}	Number of job/MWP through the PV plant
P_{PV}	Peak power generation of PV plant in MWP
JC_{WIND}	Number of job/MWP through the wind plant
DG	Diesel generator
$P^T_{WIND,each}$	Power produced by turbine
v_R	*Nominal speed of the wind turbine*
V	Wind speed
v_o	*Cut out speed*
v_J	*Cut in speed*
P_R	*Wind Generator rated power*
$P^T_{PV:each}$	Power produced by PV system
P_{RS}	PV panel rated power
R	Radiation factor
R_{cr}	certain radiation at 150 W/m^2
R_{srs}	Standard solar radiation at 1000 W/m^2
η_{BIO}	*Efficiency of the biomass*
CB_{BIO}	*Calorific value of the rise husk*
E_{TRC} is	Tradable renewable energy certificate cost in $/kWh
r_1 & r_2	Arbitrary figures value
η_{bf}	Discharging efficiency of battery bank
k	Iteration number
W	Inertia weight
$f\max_{SE}$	Element of maximum surplus energy which may be utilized for AC additional load
$e_{LY/C}$	Energy yearly electricity Consumption per capita in kWh/yr/person
$JC_{BIOMASS}$	Number of job/MWP through the biomass plant
$P_{BIOMASS}$	Power generated through the biomass plant in MW
JC_D	Number of created through diesel generator in job/GWh/yr
E_D	Yearly energy generated by diesel generator GWh/yr
$JC_{BATTERY}$	Job created by battery unit in job/MWh

opening the doors of growth for individuals and changing them into masters of their own advancement. These four standards are as following [12]:

- ➢ Equity and diversity
- ➢ Sustainability
- ➢ Empowerment
- ➢ Productivity

For the design of HRES, many authors have considered the Job Creation (JC) factor [28–32]. Clean energy can lead to many domestic job employment and a great deal of these jobs would remain local as they include infrastructure development. The economy can be stimulated by diverting the investment from energy expenses to adopting energy productivity measures which would increase job creation. A number of studies have found that better utilization of sustainable power sources and methods focused on energy efficiency gives financial advantages through employment creation, while also protecting the economy from political and monetary risks related with over-dependence on a limited set of energy advancements and fuels. We concentrate on the power region in this review as it is the biggest essential energy segment and furthermore the rapid developing division and most employment/job creation studies have been done around here [30].

The working model of off-grid PV/Biomass/wind with DG and battery unit which is connected to AC load, which is shown in Fig. 1. Generated power of hybrid system is excessive as compared to load demand; this excessive power is sold and utilized to fulfill load demand of another consumer. So that it creates new jobs because of extra works needed and also increases the human development index because of earning money. In hybrids system dump load also

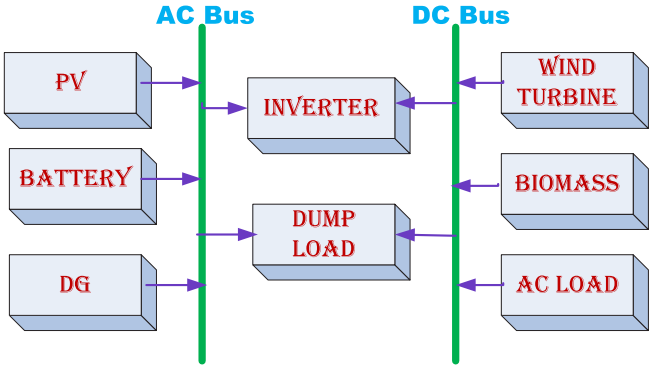

Fig. 1. General block diagram of HRES.

connected with AC side which consumes surplus energy produced from renewable sources after cover the AC load of design location, storage battery unit and additional AC load.

For the economic power supply to the consumer, dispatch strategy plays an important role. Through a proper dispatch strategy of DG, a reliable and cost-efficient operation can be done for any HRES [13,27]. A variable speed diesel generator (VSDG) has a great impact on HRES for obtaining a techno-economic system which is first introduced by Manwell [14]. Compared to other existing control dispatch strategies an optimal strategy with VSDG has many advantages as is discussed in this paper.

In the hybrid system proposed in this paper particulate matter (PM) is also considered which has not received much attention in