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Review of hybrid renewable energy systems with comparative analysis of off-grid hybrid system

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ABSTRACT

PV and wind hybrid are found to be the most lucrative solution for the diminishing traditional energy sources. Whereas these alternatives sources of the energy have many remarkable rewards like cost of energy and feasibility etc. The attributes of these sources of being cost effective and stable are possible due to their complementary nature as compared to independent energy systems. Therefore, these systems have admirable capability to meet energy crisis up to some extent. The proposed work gives the idea about various configuration, control strategy, techno-economic analysis and social effect. The findings of comprehensive review will help for further improvements in hybrid system design and control with respect to practical system implementation. This paper also presents a case study of remote area Barwani, India and results are compared using Homer and PSO. The resulting analysis reveals that configurations of hybrid system are the most techno-economical feasible solution concerning COE, renewable fraction, maximum renewable penetration, levelized cost, operating cost, mean electrical efficiency, and emission amongst various hybrid system configurations using PSO as compared to HOMER.

1. Introduction

The worldwide switching towards reliable and feasible hybrid renewable energy system is mainly due to two reasons; the potential techno-economic advantages of hybrid combinations and the rapid depletion of conventional sources of energy. In India, a large portion of remote area, not access electricity. Diesel generators (DG) is used to meet required load demand for that remote areas. Operating cost of DG is high due to fluctuation in fossil fuel cost and maintenance of generator. Therefore alternate source of energy like photovoltaic and wind along with its various hybrid combinations offer suitable options for electricity generation for off-grid area. The PV and wind renewable energy (RE) are found to be the significant nonconventional power generation option in the era of ever-increasing crises of energy with their profitable traits like environment-friendly, bulk availability, location-reliance. It has the advantage to increase the reliability and decrease the cost of the total life cycle. In Economic Times report, India's gross RE potential (up to 2022) is estimated at 175 GW [1]. The range of annual typical for solar insolation and wind speed are 5–10 m/s and 3–6 KWh/m^2 respectively is enhancing by the researchers of various countries to minimize the dependency on conventional sources [2,3].

The design consideration of wind energy based systems using appropriate technology to meet the load demand of different areas with respect to achieving various objectives is investigated. Objectives such as suitable location, assessment of present and future energy requirement, estimation of payback period, evaluation of LPSP, economic along with energy reliability analysis etc are reported [2–4,34]. The design of PV based hybrid systems [28–30,33,35,46] and PV-Wind based hybrid system [5–10,24–26,31,32,36–45,47,48] to assess the practical performance of the system using distinct methodology for a variety of geographical locations to meet the load demand are presented to obtain the widespread goals as follows:

- Optimal sizing/configuration of hybrid system components.
- Reliable operation control of hybrid system.
- Minimize the annual COE
- Minimize LPSP for a given load.
- Satisfy the load demand by effective use of renewable sources.
- Decrease the pollutant emissions.
- Improve battery efficiency.
- Higher conversion efficiency.
- Reasonable price and ease of operation.
- Estimation of the loss-of-load probability (LLP).
- Minimize costs of O & M of the PV sections and the battery.
- Minimize life cycle costs and ensuring reliable system operation by appropriate design and process control of HRES.

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Nomenclature

DG	Diesel generators
GTREI	Global Trends in Renewable Energy Investments
IEA	International Energy Agency
LLP	loss of load probability
HRES	Hybrid renewable energy systems
$\mathbf{P^T_{WIND,each}}$	**Power by wind turbine**
$\mathbf{v_r}$	**Nominal speed of wind turbine**
V	**Wind speed**
$\mathbf{v_o}$	**Cutout speed**
$\mathbf{v_J}$	**Cut in speed**
$\mathbf{P_{RW}}$	**Wind generator rated power**
τ	The hourly self-discharge rate
LOLR	Loss of load risk
$\mathbf{P^T_l}$	Energy demand of the particular hour
$\mathbf{\eta_{inverter}}$	Efficiency of the inverter
IMD	Indian meteorological data
NASA	National Aeronautics and Space Administration
O/M	Operation & maintenance
CO_2	Carbon dioxide
RE	Renewable energy
PV	Photovoltaic
$P_{PV,each}$	Power generated by PV system.
P_{RS}	PV panel rated power.
R	Solar radiation factor.
R_{cr}	Certain radiation
R_{srs}	Standard solar radiation
η_G	DG efficiency
N	No. of swarm
$\mathbf{P^T_{WIND}}$	Power generated by wind turbine.
$\mathbf{P^T_{PV}}$	Power generated by PV panel
$\mathbf{P^T_{BIO}}$	Power generated by Biomass
$\mathbf{P^T_l}$	Energy demand for the particular hour.
$\mathbf{\eta_{bc}}$	Charge efficiency of the battery bank
LA	Load Autonomy
HLOL	Hour's which loss of load occurs
HTOT	Hour's operation system
LPSP	Loss of Power Supply Probability
LLP	Loss of Load Probability
UL	Unmet Load
TNPC	Total net present cost
NPW	Net present worth
C_{ANN}	Annualized cost,
CRF	Capital recovery factor,
i	Interest rate,
T_{PLT}	Project lifetime
LCC	Life cycle costs
COE	Cost of energy
NOx	Nitrogen oxide
SO2	Sulfur dioxide
$\mathbf{E^T_{battery}}$ and $\mathbf{E^{T-1}_{battery}}$	Charge measure of the battery at time T and T-1
GA	Genetic algorithm
CO	Carbon monoxide
PSO	Particle swarm optimization
$\mathbf{F_{dsl}}$	**Diesel fuel consumption l/h**
P(t)	**DGpower(kW)**
$\mathbf{P_R}$	**Rated power of the DG**
A, **B**	Are the costand parameters (l/kW), constant value is a round 0. 08145 and 0. 246
$\mathbf{F_{dsl}}$	**Diesel fuel consumption l/h**
P(t)	**DG power (kW)**
η_T	Total efficiency
η_B	Thermal efficiency
k	k^{th} iteration number
w	Inertia weight
r_1 & r_2	Random numbers
c_1 & c_2	Velocity coefficients
DOD	Dept of discharge

- Minimize the total annual cost including initial cost, operation cost and maintenance cost etc.

The various strategies for modeling and control of hybrid system using different methodologies and software such as different dispatch strategies and different design software namely PVSYST, SolSim and Hybrid Designer, HYBRID2, SOME, PHOTO, HOMER, SEU-ARES, ARES, F-Chart Software, RAPSYS and RETScreen etc are developed [11–23,27,49,50]. The PV-wind HRES with battery unit and DG as a support be capable of electrifying the remote area population where it

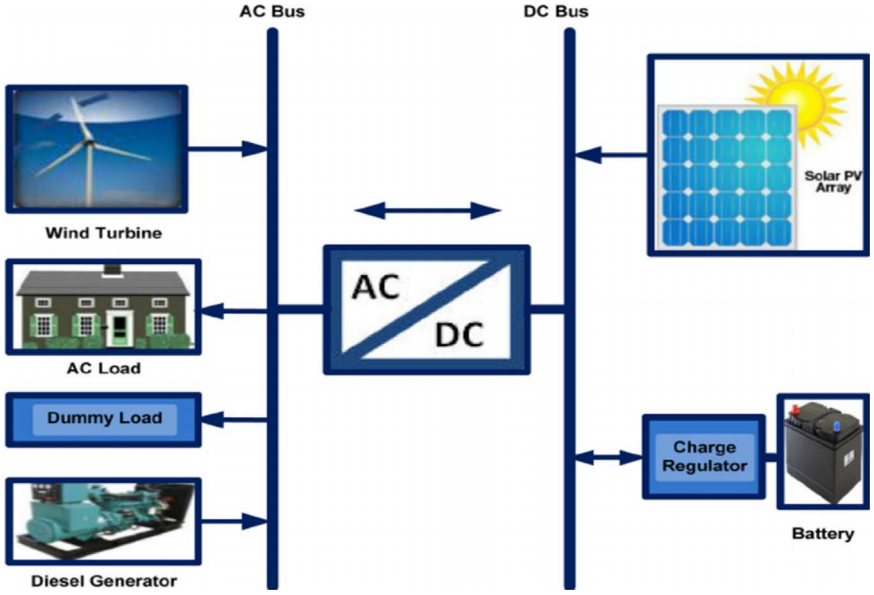

Fig. 1. Block diagram of a typical PV-wind hybrid system.