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Review of recent trends in optimization techniques for solar photovoltaic–wind based hybrid energy systems

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ABSTRACT

An update literature review on trends in optimization techniques used for the design and development of solar photovoltaic–wind based hybrid energy systems is presented. The main objective is to identify latest promising techniques for the optimization of solar photovoltaic (PV)–wind based hybrid systems. Different techniques used by researchers for the optimization of renewable based hybrid energy systems are reviewed along with PV–wind based hybrid system sizing methodology, is presented. Optimization studies during last 2.5 decades by researchers using traditional and new generation methods are analyzed and sixteen optimization methods including hybrid algorithms are presented. The trend shows that new generation artificial intelligence algorithms are mostly used during last decade as these require less computation time and have better accuracy, good convergence in comparison to traditional methods. The study suggests using hybridization of two or more algorithms to overcome the limitations of a single algorithm. Additionally some other techniques are identified for follow up research in the design of PV–wind hybrid systems. This review will be useful for researchers to face complexity and challenges in renewable energy based hybrid system research.

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Contents

1. Introduction . . . 756
2. PV–wind hybrid system sizing methodologies . . . 757
   2.1. Requirements for PV–wind hybrid system optimization . . . 757
      2.1.1. Meteorological data . . . 757
      2.1.2. Load profile . . . 757
      2.1.3. System configuration . . . 757
      2.1.4. Energy system model . . . 757
      2.1.5. Optimization results . . . 760
   2.2. Criteria for PV–wind hybrid system optimization . . . 760
      2.2.1. Reliability analysis . . . 760
      2.2.2. Cost analysis . . . 760
   2.3. Modeling of hybrid system components . . . 760
      2.3.1. Modeling of photovoltaic system . . . 761
      2.3.2. Modeling of wind generator system . . . 761
      2.3.3. Modeling of battery system . . . 761
   2.4. Conditions and steps for the execution of a hybrid optimization problem . . . 761
3. Optimization techniques used in PV–wind based hybrid research . . . 761
   3.1. Traditional approach for optimization . . . 762
      3.1.1. Graphical construction technique . . . 762
      3.1.2. Iterative techniques . . . 762
      3.1.3. Probabilistic approach . . . 762

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3.1.4. Trade-off approach. . . . 762
3.1.5. Linear programming technique 762
3.2. New generation approach for optimization 763
3.2.1. Genetic Algorithm 763
3.2.2. Particle swarm optimization (PSO) 764
3.2.3. Simulated annealing (SA) 764
3.2.4. Other new generation approaches 764
3.2.5. Hybrid algorithm optimization techniques. 765
4. Discussion 766
5. Conclusion 767
References 767

Nomenclature

V_{ci}	cut-in wind speed
V_{co}	cut out wind speed
I_b	direct normal solar radiations
$P_{faliure}$	load which cannot be served within a time period
P_w	power output from wind turbine generator.
η_{PV}	PV system efficiency
P_r	rated power of a wind turbine
V_r	rated speed of the wind turbine
α	power law exponent
P_{total}	total load
C_B	cost of battery bank
C_{other}	cost of other systems and accessories
C_w	cost of wind system
I_d	diffuse solar radiations
η_w	efficiency of wind turbine generator and corresponding converter,
$E_{deficit}$	energy deficit within a certain time period (t)
P_{load}	load demand during a period
η_m	module efficiency
η_{pc}	power conditioning equipment efficiency
$T_{failure}$	power failure time period
P_s	power generated from solar PV system
I_T	solar radiation on a tilted surface
R_d	tilt factor for the diffused solar radiation.
R_r	tilt factor for the reflected solar radiation.
H_{total}	total hours of operation
H_{LOL}	total number of hours during which loss of load (LOL) occurs
A_w	total swept area
C_{total}	total system cost
T_{total}	total working time
$\beta=$	array efficiency temperature coefficient
$CRF=$	capital recovery factor
$T_c=$	cell temperature
$\eta_c=$	charge efficiency (depends on the SOC and the charging current and has a value between 0.65 and 0.85)
$C_{s=}$	cost of solar PV system
$\eta_{dis=}$	discharge efficiency (generally taken equal to 1)
$\sigma(t)_=$	hourly self-discharge rate depending on the battery state (taken constant at about 0.02%)
$i_=$	interest rate
$C_{bat=}$	nominal capacity of the battery (A h).
$P_{w=}$	power generated from wind turbine
$T_{proj=}$	project life time
$A_{PV=}$	PV system area
$T_{r=}$	reference temperature for cell efficiency
$C_{ann=}$	total annualized cost
$P_{load=}$	total load to be delivered or load demand
$P_{total=}$	total power generated from resources
COE	cost of energy
DOD	depth of discharge,
LA	level of autonomy
LCC	life cycle cost
LLP/LOLP	loss of load probability
LOLH	loss of load hours
LOLR	loss of load risk
LPSP	loss of power supply probability
NPC	net present cost
p	cumulative probability of meteorological status which corresponds to electrical energy generation
q	probability of failure
SOC	state of charge
SPL	system performance level
UL	unmet load
V and V_0	wind speeds at heights h and h_0 (h_0 is the reference height).

1. Introduction

The fossil fuel resources are becoming scarce due to ever increasing energy demand in commercial, industrial, agricultural and domestic sector. In this context, alternative energy resources like solar, wind, biomass, bio-fuel, hydro and geothermal etc. are being utilized largely to generate power in recent years. A renewable energy based hybrid system offers a better option than a single source based system in terms of cost, reliability and efficiency. One or more energy sources can be utilized in renewable energy based hybrid systems (REHS) which can work as stand alone or in a grid connected mode. Different types of hybrid system combinations are feasible depending on the need and resource availability at a particular location, but in the present study we have focused only on PV–wind based hybrid systems as solar and wind are most promising power generating sources due to their complementary nature advantage. Wind speeds are often low in periods when the solar resource is at its best. On the other hand, the wind is often stronger in seasons when there are less solar resource. But these sources depend on climatic conditions which are unpredictable thus making the design of a hybrid system complex. In order to improve the reliability of a PV wind hybrid system other sources like fuel cell, diesel generator can also be integrated. Such a hybrid system can meet the basic power requirements in a non-electrified remote area where grid power is not available. Besides this our main research focus in the present

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