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Multi-objective Design procedure for hybrid (wind–photovoltaic) system by GA

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Abstract: The optimal sizing for power reliable Wind-PV hybrid system is time consuming and complex due to varying weather conditions and the corresponding system cost .This requires a novel sizing procedure which can able to find number of possible solution .This paper proposes a multi-Objective design procedure using the genetic algorithm (GA) and integer programming with LPSP concept which has the ability to attain the global optimum with relative computational simplicity to minimize system cost and Loss of supply probability.

Keywords: Wind/PV; standalone power systems; optimal configuration; genetic algorithms; mixed multiple criteria integer programming.

I. INTRODUCTION

Global environmental concerns and the ever-increasing need for energy, coupled with a steady progress in renewable energy technologies are opening up new opportunities for utilization of renewable energy resources. Hybrid wind/ photovoltaic (PV) power systems are one important type of standalone renewable energy power systems. The hybrid combination of PV panels and wind turbine generators (WTGs) improves overall energy output and reduces energy storage requirements on proper sizing of wind–photovoltaic hybrid systems (WPHSs).The aim for sizing is to guarantee the lowest investment with a reasonable and full use of the PV system, wind system, and battery bank at the desired conditions in terms of investment and energy requirement of the specific load. Larger sizing results would cause higher investment whereas smaller sizing may cause load supply discontinuity for a particular load. The objective of this paper is to size optimal PV/Wind/batteries hybrid systems by minimizing two objectives function which are the Loss of Power Supply Probability (LPSP) and the Annualized Cost of System (ACS) The decision variables included in the optimization process are the PV module number, wind turbine number, battery number, and also the PV module slope angle as well as the wind turbine installation height. The methodology developed was applied using the solar irradiation, the temperature and the wind speed collected on the site.

II. STRUCTURE OF THE STUDIED SYSTEM

A hybrid solar-wind-battery power generation system consists of a PV array, a wind turbine, a battery bank, a controller and an inverter. A schematic diagram of the basic hybrid system is shown in Fig 1. The PV array and the wind turbine work together to meet the load demand. When the energy sources (solar and wind energy) are sufficient, the generated power, after meeting the load demand, provides energy to the battery until its full charge. However, when energy sources are inferior to the load demand, battery gives required energy.

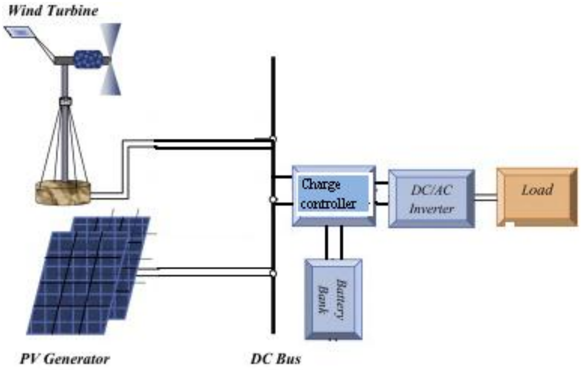


Fig.1General Diagram of a hybrid (wind–PV) system

III. MATHEMATICAL MODEL OF PV SYSTEM

Modeling the generated energies from wind turbines and PV modules together with the storage battery constitutes the critical step for optimization. Information regarding the operating performances of system components given in Fig. 1 play important role in accurate modeling. There are a number of mathematical models in the literature for both PV modules and wind generators. Many of these models consider a variety of physical factors for improving accuracy. However, the aim of this study is to illustrate a novel insight to the WPHS modeling and to introduce an efficient sizing strategy. Therefore, complicated component models are avoided and basic mathematical models that characterize the system are used for clarity. PV module performance is highly influenced solar radiation and PV module temperature. A simplified simulation model (Zhou et al., 2007) with acceptable precision is used to estimate the actual performance of PV

$$P\,\mathrm{mod}\,ule = \frac{\dfrac{V_{oc}}{\eta mpp * KT/q} - \ln\left(\dfrac{Voc}{\eta mmp\; KT/q} + 0.72\right)}{1 + \dfrac{V_{oc}}{\eta mpp * KT/q}} * \left(1 - \frac{Rs}{Voc/Isc}\right)$$

$$* Isco(G/G0)^{\alpha} * \frac{Voc}{1 + \beta \ln(G/G0)} * (To/T)^{\gamma}$$

modules under varying operating conditions. Five parameters (α, β , γ , Rs and ηmpp) are introduced to take account for all the nonlinear effects of the environmental factors on PV module performance. Using the definition of fill factor, the maximum power output delivered by the PV module can be written as

where ηmpp is the ideality factor at the maximum power point (1 < ηmpp < 2), because the PV systems are usually equipped with a maximum power point tracker to maximize power output, it is reasonable to believe that the PV module working states will stay around the maximum power point. Therefore, ηmmp is used to present the ideality factor of the PV module. K is the Boltzmann constant (1.38×10-23 J/K); T is the PV module temperature, K; q is the magnitude of the electron charge (1.6×10-19 C); Rs is the series resistance, ohm; α is the factor responsible for all the nonlinear effects that the photocurrent depends on; β is a PV module technology specific-related dimensionless coefficient (Van Dyk et al., 2002); and γ is the factor considering all the nonlinear temperatur–voltage effects. if a matrix of Ns · Np PV modules is considered, the maximum power output of the PV system can be calculated by

$$Ppv = Np * Ns * P\,\mathrm{mod}\,ule * \eta mppt * \eta oth$$

Where ηmpp is efficiency of the maximum power point tracking, ηoth is the factor representing the other losses such as the loss caused by cable resistance, accumulative dust, etc. Thus, once the solar radiation on the module surface and the PV module temperature are known, the power output of the PV system can be predicted.

Table no.1 Parameter estimation results for the PV module performance

Item	α	β	γ	η mpp	Rs(Ω)
	1.21	0.058	1.15	1.17	0.012

$$v = v_r\left(\frac{Hwt}{Hr}\right)^{\xi} \quad \text{.........Eq.1}$$

$$WindPower = \frac{1}{2}\rho A v^{3} \quad \text{... Equ.2}$$

Where v is the wind speed at the wind turbine height HWT, m/s; vr is the wind speed measured at the reference height Hr, m/s; and the parameter ξis the wind speed power law coefficient. The value of the coefficient varies from less than0.10 for very flat land, water or ice to more than 0.25 for heavily forested landscapes.

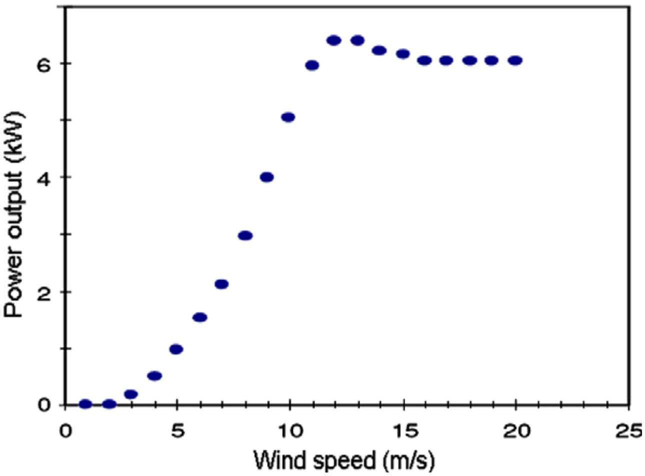


Fig.no-2 Wind power curve.

V.BATTERY MODEL

The battery bank, which is usually of the lead-acid type, is used to store surplus electrical energy, to regulate system voltage and to supply power to load in case of low wind speed and/or low solar conditions. Lead-acid batteries used in hybrid solar–wind systems operate under very specific conditions, and it is often very difficult to predict when energy will be extracted from or store in battery. Most battery models mainly focus on three different characteristics, i.e. the battery state of charge (SOC) as well as the floating charge voltage (or the terminal voltage) and the battery life time. In this paper only the battery state of charge (SOC) is taken between 0.7 to 0.9 for simplicity.

VI.RELIABILITY BASED LPSP CONCEPT

A reliable electrical power system means a system has sufficient power to feed the load demand during a certain period or, in other words, has a small loss of power supply Probability (LPSP). LPSP is defined as the probability that an insufficient power supply results when the hybrid system (PV array, wind turbine and battery storage) is unable to satisfy the load demand (Yang et al., 2003).It is given as

$$LPSP = \frac{\sum_{t=0}^{T} Powerfailu\ retime}{T}$$

$$LPSP = \frac{\sum_{t=0}^{T} Poweravail\ ble - Powerneede\ d}{T}$$

VII. ECONOMICAL MODEL BASED ON ACS CONCEPT

The economical approach, according to the concept of annualized cost of system (ACS) is developed to be the best benchmark of system cost analysis in this study. According to the studied hybrid solar-wind- battery system, the annualized cost of system is composed of the annualized capital cost Cacap, the Annualized maintenance cost Camain and the annualized replacement cost Carep

ACS=Cacap(PV+Wind+Bat+Tower+Other)+Carep(Bat)+ Ca main(PV+Wind+Bat+Tower+Others

VIII.GENETIC ALGORITHMS

Genetic algorithm (GA) based optimization is proposed for optimization. A GA is a search technique categorized as global search heuristics. It is used for finding exact or approximate solutions to optimization problems. A GA is implemented as a computer simulation in which a population of candidate solutions to an optimization problem (called individuals) evolves towards better solutions. The technique is inspired by evolutionary biology phenomena like inheritance, mutation, selection, and crossover (also called recombination).

IX. SYSTEM OPTIMIZATION MODEL WITH GENETIC ALGORITHM

The following optimization model is a simulation tool to obtain the optimum size or optimal configuration of a hybrid solar–wind system employing a battery bank in terms of the LPSP technique and the ACS concept by using a genetic algorithm and multi integer programming as shown below.

1. Input Wind speed, solar radiation and Temperature.
2. Select Set of βand Wind turbine height by GA with initial population of 10 values.
3. Assuming Sets of 20 combination of Npv,Nwt,Nbat basis on targeted cost.
4. Calculation of power generated for recorded values of β and Tower height.
5. Save record of Power generated for Various values of Slop angle and Tower height for EachSelected set of Npv,NBat,Nwt.

The decision variables included in the optimization process are the PV module number NPV, wind turbine number NWT, battery number Nbat, PV module slope angle β and wind turbine installation height HWT. A year of hourly data including the solar radiation on the horizontal surface, ambient air temperature, wind speed and load power consumption are used in the model. The initial assumption of system configuration will be subject to the following inequalities constraints.

$Min(Npv, Nwind, Nbat) \geq 0$
$Hlow \leq Hwt \leq Hhigh$
$0^0 \leq \beta' \leq 90^0$

X.RESULT

The proposed method has been applied to hybrid project which supply 3.5 KW AC load. To find optimum sizing The technical characteristics of the PV module and battery as well as the wind turbines power curve used in the studied project are given in Tables 5 and 6 and Fig. 2.The The values taken for Average monthly solar radiation on the horizontal plane and the wind speed (30 m above the ground) distribution probability is plotted in Fig. 3.

Optimal sizing results for the hybrid solar–wind system for LPSP = 1% and 2%

Table.No.3

Loss of Power Supply Probability LPSP (%)	1%	2%
Number of PV modules	35	28
Number of Wind turbines	1	1
Number of batteries	10	9
Annualize Cost System	17,750USD	16,980 USD
Heght of Wind turbine	45m	43m
Slope angle	37	37

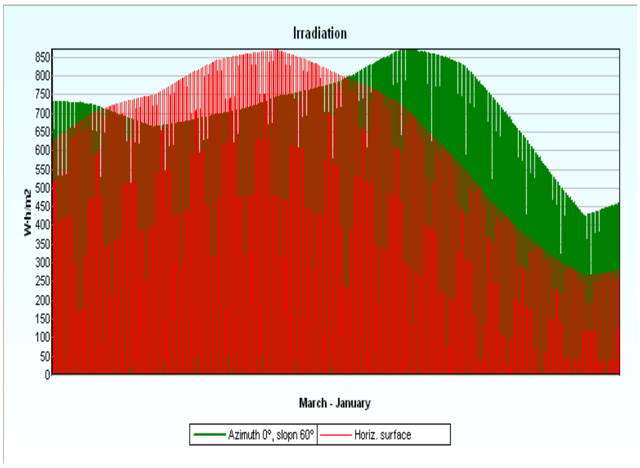


Fig.No3

Table No.5

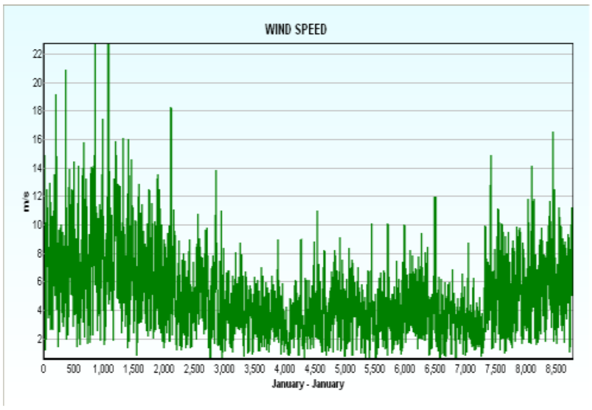
Specification of PV Module				
Voc	Ioc	Imax	Vmax	Pmax
21Volt	6.5Amp	5.75Amp	17volt	100watt

Table No.6

Specification of battery		
Rated capacity(Ah)	Voltage (volt)	Charging Efficiency
1000	24	90

XI.CONCLUSION

The major aspects in the design of a hybrid new and renewable generation system are the reliable power supply of the consumer under varying atmospheric conditions and the corresponding total system cost. In this paper, a simple and effectual sizing procedure for hybrid (wind–photovoltaic) system with GA for optimal combination and sizing of hybrid, stand alone renewable generation system has proposed. A simple mathematical modeling for each component of hybrid wind-PV generation system was developed. Using the models, the method of optimal combination and sizing of the hybrid system components was developed. Also, a very simple model was considered as the economical configurations. The method aims at finding the configuration, among a set of system components, which meets the desired system requirements, with the lowest value of the system cost.



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