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On Recent Advances in Electrical Engineering

Optimal sizing of Autonomous Wind-PV hybrid system by Genetic Algorithm with LPSP technology

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ABSTRACT:-*The optimal sizing of a small autonomous hybrid power system can be a very challenging task, due to the large number of design settings and the intermittent nature of solar and wind energy sources. This problem belongs to the category of combinatorial optimization, and its solution based on the traditional method of exhaustive enumeration can be proved extremely time-consuming. This paper proposes a methodology for optimization of hybrid power generation and improves reliability of Existing Power Generation Scheme with the help of Genetic Algorithm.*

Keywords:- *Combinatorial optimization, genetic algorithm by HOGA software ,MATLAB,, renewable energy sources, Small autonomous hybrid power systems.*

I. INTRODUCTION

The growing depletion of natural resources, renewable energies have attracted much attention among available renewable energy technologies, wind and solar energy are the most promising options. Although these technologies are improving in various aspects, the drawbacks associated with them, such as their intermittent nature and high capital cost, remain the main obstacles for their utilization. Because of the intermittent solar radiation and wind speed characteristics, which highly influence the resulting energy production, power reliability analysis has been considered as an important step in any system design process. 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. It is a feasible measure of the system performance for an assumed or known load distribution. A LPSP of 0 means the load will always be satisfied; and an LPSP of 1 means that the load will never be satisfied. Loss of power supply probability (LPSP) is a statistical parameter; its calculation is not only focused on the abundant or bad resource period. Therefore, in a bad resource year, the system will suffer from a higher probability of losing power. This paper proposes a methodology for optimization of hybrid power generation and improves reliability of Existing Power Generation Scheme with the help of Genetic Algorithm.
Various optimization techniques such as the probabilistic approach, graphical construction method and iterative technique have been recommended by researchers.

Tina et al. (2006) presented a probabilistic approach based on the convolution technique to incorporate the fluctuating nature of the resources and the load, thus eliminating the need for time-series data, to assess the long-term performance of a hybrid solar–wind system for both stand-alone and grid-connected applications.

Yang et al. (2003, 2007) have proposed an iterative optimization technique following the loss of power supply probability (LPSP) model for a hybrid solar–wind system. The number selection of the PV module, wind turbine and battery ensures the load demand according to the power reliability requirement, and the system cost is minimized.

A common disadvantage of the optimization methods described above is that they still have not found the best Compromise point between system power reliability and system cost. The minimization of system cost function is normally implemented by employing probability programming techniques or by linearly changing the values of corresponding decision variables, resulting in suboptimal solutions and sometimes increased computational effort requirements. Also, these sizing methodologies normally do not take into account some system design characteristics, such as PV modules slope angle and wind turbine installation height, which also highly affect the resulting energy production and system installation costs.

In this paper, one optimal sizing model for a stand-alone hybrid solar–wind system employing battery banks is developed based on the loss of power supply probability (LPSP) and the annualized cost of system (ACS) concepts. The optimization procedure aims to find the configuration that yields the best compromise between the two considered objectives: LPSP and ACS.

II. Model of the hybrid system components

A hybrid solar–wind power generation system consists of PV array, wind turbine, battery bank, inverter, controller, and other accessory devices and cables. A schematic diagram of the basic hybrid system is shown in Fig. 1. The PV array and wind turbine work together to satisfy the load demand. When energy sources (solar and wind energy) are abundant, the generated power, after satisfying the load demand, will be supplied to feed the battery until it is full charged. On the contrary, when energy sources are poor, the battery will release energy to assist the PV array and wind turbine to cover the load requirements until the storage is depleted. In order to predict the hybrid system performance, individual components need to be modeled first and then their mix can be evaluated to meet the load demand.

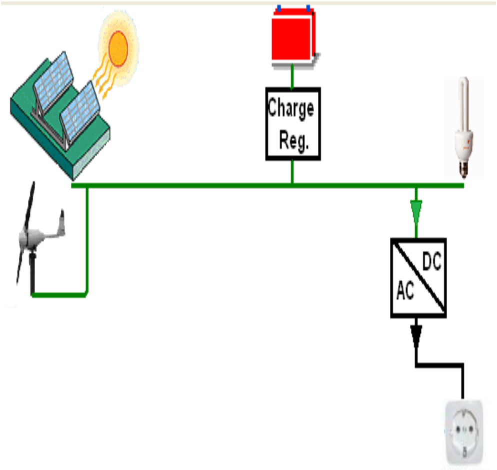


Fig.1

2.1 PV system model

PV module performance is highly affected by weather conditions, especially 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 modules under varying operating conditions. The Number of PV panels, Maximum Power point tracking efficiency (ηmmp),Temperature of PV panel(T),Fill Factor(α),Series resistance(Rs) and Panel Slope angle (β) are Taken in to account for all the nonlinear effects of the environmental factors on PV module performance. PV modules represent the fundamental power conversion unit of a PV system, if a matrix of Ns · Np PV modules are considered, the maximum power output of the PV system can be calculated by

Eq.1···

$$P\,module = \frac{\dfrac{V_{oc}}{\eta mmp * KT/q} - \ln\left(\dfrac{Voc}{\eta mmp\ KT/q} + 0.72\right)}{1 + \dfrac{V_{oc}}{\eta mmp * KT/q}} * \left(1 - \frac{Rs}{Voc/Isc}\right) * Isco(G/G0)^{\alpha} * \frac{Voc}{1 + \beta \ln(G/G0)} * (To/T)^{\gamma}$$

In order to calculate the these parameters, only limited data are needed. The detailed data used for the parameter evaluation are listed in Table 1, they are the short-circuit current Isc, open-circuit-voltage Voc, maximum power point current IMPP and voltage VMPP of the PV module under two different solar irradiance intensities (G0, G1) and two PV module temperatures (T0, T1). These data are normally available from the manufactures, and the regression results for the PV module used in this study are given in Table 1. Then the simulation model can be used for PV module performance predictions plotted in fig-4.

$$Ppv = Np * Ns * P\,module * \eta mppt * \eta oth \qquad \text{...Eq.2}$$

		Table-1				
Item	α	β	γ	n mpp	Rs(Ω)	
	1.21	0.058	1.15	1.17	0.012	

2.2 Wind turbine system model

Choosing a suitable model is very important for wind turbine power simulations. There are three main factors that determine the power output of a wind turbine, i.e. the power output curve (determined by aerodynamic power efficiency, mechanical transmission gm and converting electricity efficiency ηgg) of a chosen wind turbine, the wind speed distribution of a selected site where the wind turbine is installed, and the tower height. The power curve of a wind turbine is nonlinear, the data is available from the manufacturer, and can be easily digitized and the resulting table can be used to simulate the wind turbine performance. Wind speed changes with height and the available wind data at different sites are normally measured at different height levels. The wind power law has been recognized as a useful tool to transfer the anemometer data recorded at certain levels to the desired hub center:

… Eq.3 $$v = v_r \left(\frac{Hwt}{Hr}\right)^{\xi}$$ … Eq.4 $$WindPower = \frac{1}{2}\rho A v^3$$

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;
ρ-Air density (kg/m^3);
A-Swept area of rotor blade(m^2)and
The parameter ξ is the wind speed power law coefficient.
The value of the coefficient varies from less than 0.10 for very flat land, water or ice to more than 0.25 for heavily forested landscapes. The one-seventh power law (0.14) is a good reference number for relatively flat surfacessuch as the open terrain of grasslands away from tall trees or buildings (Gipe, 1995)

2.3 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.

III. Power reliability model based on LPSP concept

Because of the intermittent solar radiation and wind speed characteristics, which highly influence the resultingenergy production, power reliability analysis has been considered as an important step in any system design process.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). Loss of power supply probability (LPSP) is a statistical parameter measure of the system performance for an assumed or known load distribution.

Eq.5….
$$LPSP = \frac{\sum_{t=0}^{T} Powerfailuretime}{T}$$
$$LPSP = \frac{\sum_{t=0}^{T} Poweravailble - Powerneeded}{T}$$

where T is the number of hours in this study with hourly weather data input. The power failure time is defined as the time that the load is not satisfied when the power generated by both the wind turbine and the PV array is insufficient and the storage is depleted.

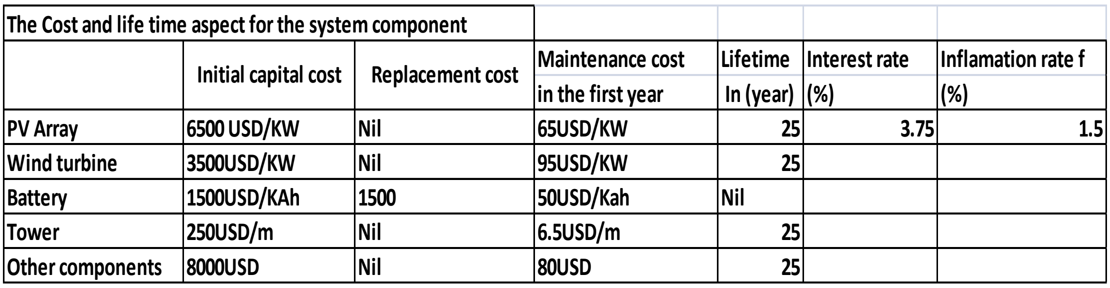
IV. The annualized capital cost concept

The optimum combination of a hybrid solar–wind system can make the best compromise between the two considered objectives: the system power reliability and system cost. 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 system, the annualized cost of system is composed of the annualized capital cost Cacap, the annualized replacement costarred and the annualized maintenance cost Camain. Five main parts are considered: PV array, wind turbine, battery, wind turbine tower and the other devices. The other devices are the equipments that are not included in the decision variables, including controller, inverter and rectifier (if it is necessary when the wind turbine is designed to have AC output). Then, the ACS can be expressed by

$$ACS = C_{acap}(PV+Wind+Bat+Tower+Other) + C_{arep}(Bat) + C_{amain}(PV+Wind+Bat+Tower+Others) \quad \text{......Eq.6}$$

V. System optimization model with genetic algorithm

Due to more variables and parameters that have to be considered, the sizing of the hybrid solar–wind systems is much more complicated than the single source power generating systems. This type of optimization includes economical objectives, and it requires the assessment of long term system performance in order to reach the best compromise for both power reliability and cost. The minimization of the cost (objective) function is implemented employing a genetic algorithm (GA),By HOGA software.



The Cost and life time aspect for the system component						
	Initial capital cost	Replacement cost	Maintenance cost in the first year	Lifetime In (year)	Interest rate (%)	Inflamation rate f (%)
PV Array	6500 USD/KW	Nil	65USD/KW	25	3.75	1.5
Wind turbine	3500USD/KW	Nil	95USD/KW	25		
Battery	1500USD/KAh	1500	50USD/Kah	Nil		
Tower	250USD/m	Nil	6.5USD/m	25		
Other components	8000USD	Nil	80USD	25		

VI. Methodology of the optimization model

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. The flow chart of the optimization process is illustrated in Fig. 3.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 b0 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:

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

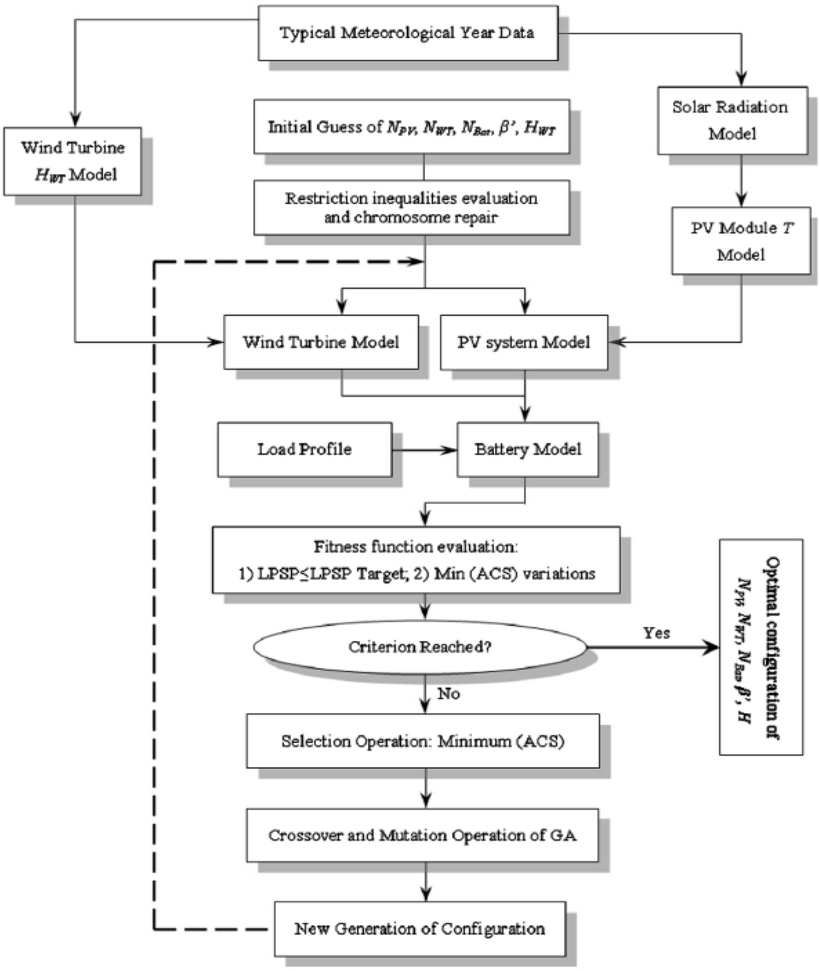


Fig-2

The PV array power output is calculated according to the PV system model by using the specifications of the PV module as well as the ambient air temperature and solar radiation conditions. The wind turbine performance calculations need to take into account the effects of wind turbine installation height. The system configuration will then be optimized by employing a genetic algorithm, which dynamically searches for the optimal configuration to minimize the annualized cost of system (ACS). For each system configuration, the system's LPSP will be examined for whether the load requirement (LPSP target) can be satisfied. Then, the lower cost load requirement satisfied configurations, will be subject to the following crossover and mutation operations of the GA in order to produce the next generation population until a pre-specified number of generations has been reached or when a criterion that determines the convergence is satisfied. So, for the desired LPSP value, the optimal configuration can be identified both technically and economically from the set of configurations by achieving the lowest annualized cost of system
(ACS) while satisfying the LPSP requirement.

VII. Results

The proposed method has been applied to analyze one hybrid project, which is designed to supply power for a Aadivasi Ashram School located At. Village Jamb Dist.Yawatmal Maharashtra,India. According to the project requirements and technical considerations, a maximum power consumption of 5 KW AC load are chosen. 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 4 and 5 and Fig. 4 and Fig.5.The lead-acid batteries employed in the project are specially designed for deep cyclic operation in consumer applications like the hybrid solar–wind systems. The daily solar radiation on the horizontal plane and the wind speed (30 m above the ground) distribution probability is plotted in Fig. 5.

Hybrid solar–wind systems usually meet load demands well because of the good complementary effect of the solar radiation and wind speed. The optimal sizing results for the LPSP of 1% and 2% resulting in a minimum annualized cost of system of US$10,600 andUS$9,708 respectively.

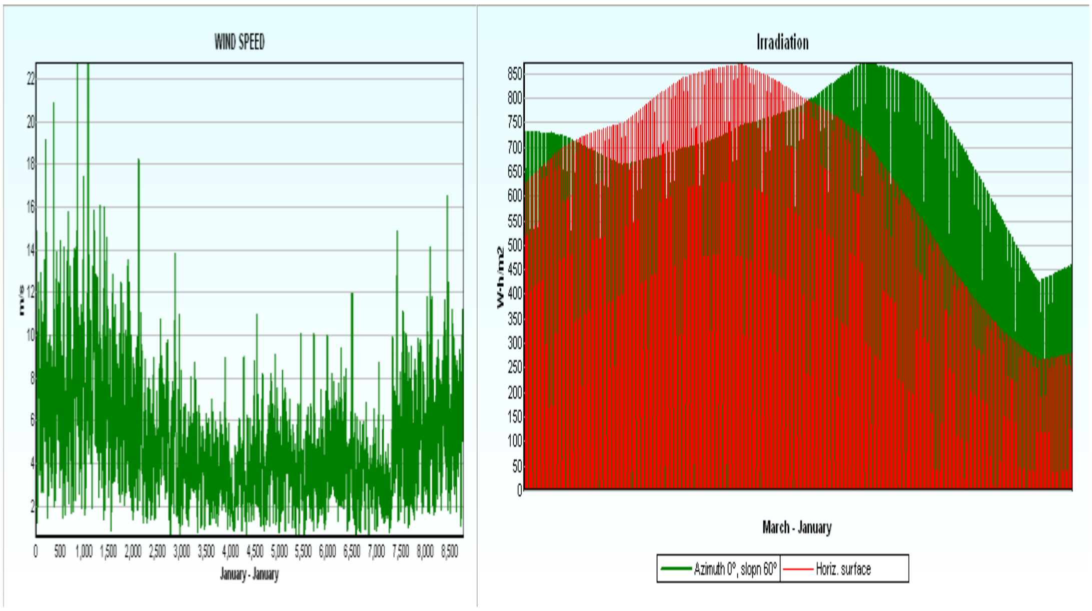


Fig-3 Meteorological conditions for optimal design

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

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

Table- 4

Table-5

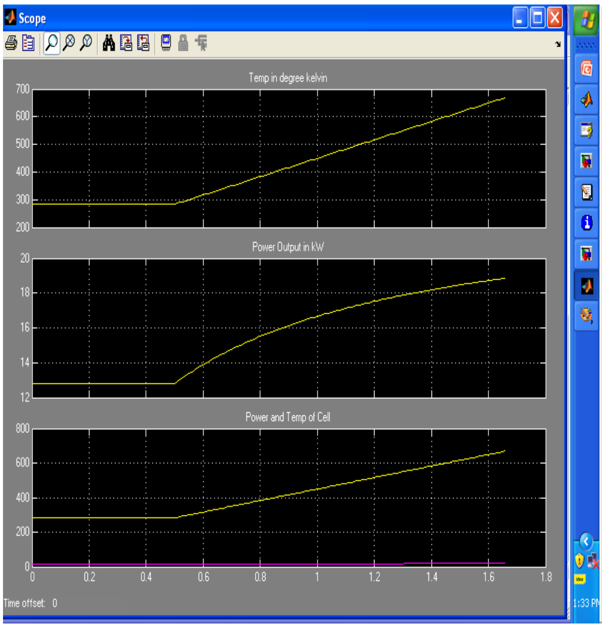


Fig-4 Power output from PV Module

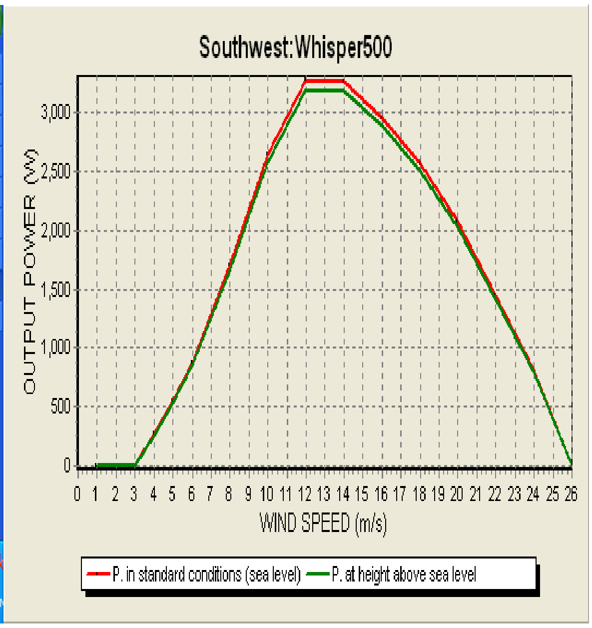


Fig-5

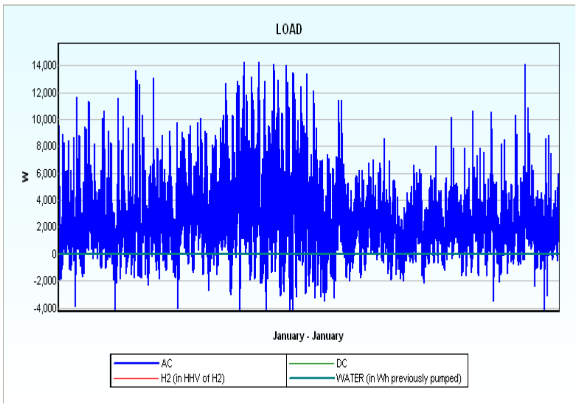


Fig.6Load curve

VIII. CONCLUSION

In order to utilize renewable energy resources of both solar and wind energy efficiently and economically, one optimum match design sizing method is developed in this paper based on a genetic algorithm (GA), which has the ability to attain the global optimum with relative computational simplicity compared to the conventional optimization methods. The model can be used to calculate the system optimum configuration which can achieve the desired loss of power supply probability (LPSP) with minimum annualized cost of system. The model can be used to calculate the system optimum configuration which can achieve the desired loss of power supply probability (LPSP) with minimum annualized cost of system. The decision variables included in the optimization process are the PV module number, wind turbine number, battery number, PV module slope angle and wind turbine installation height.

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