

An Appraisal of Optimal Sizing Techniques of Autonomous power system for renewable sources

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Abstract: Integrating wind generation, photovoltaic power, and battery storage to form hybrid power systems has been recognized to be promising in renewable energy development. In this study, various sizing algorithms developed to size hybrid (wind/PV) renewable energy systems are reviewed as a first step. Then a case study is performed to find optimum size of a small hybrid (wind/PV) system considered to be built. This paper proposes the fine-tuned algorithm for optimal sizing of the APSFRS (Autonomous power system for renewable sources). Due to large number of design setting and the sporadic nature of solar and wind energy sources it becomes very challenging. The modelling a wind solar hybrid system is considered in the procedure of optimal sizing methodology. While in second step optimum sizing of a system is done according to probability (LPSP). Then it is also analyzed with traditional method of exhaustive enumeration can be proved extremely time-consuming by Genetic Algorithm and the exhibition a comprehensive method for optimum sizing of hybrid energy systems using intelligence evolutionary algorithms is performed. Then the fuzzy c-means clustering also discussed finally compared with the general FCM method and chronological method to validate the effectiveness of the mentioned methods.

Keywords: Optimal sizing, genetics algorithm, intelligence evolutionary algorithms, fuzzy c-means clustering, autonomous power system, renewable energy sources.

1. Introduction :

Cost effective sizing of wind-PV (Photovoltaic) systems is very important to decrease initial cost of the system. In renewable applications wind and solar systems are widely used in a hybrid hierarchy. The main reason of this combination is the discrete behavior of wind and solar energy generations. A common drawback of wind and solar energy is their wind speed characteristic and intermittent solar radiation. The problem is partially overcome by using these systems together with a storage component. The development of wind power in India began in the 1990s and has significantly increased in the last few years. It is estimated that 6,000 MW of additional wind power capacity will be installed in India by 2012. A Hybrid PV/Wind system with storage banks

presents an unbeatable option for the supply of small electrical loads at remote locations where there is no utility grid power supply. The fast development of renewable energies brought new complex problems of combinatorial optimization in particular as regards the autonomous hybrid energy systems. These systems involve several energy sources as wind, biomass or sun and are not connected to the grid. They are particularly useful in islands as La Réunion [1] and in remote areas as there are in Canada [2]. Mathematical techniques have been used to optimize either the operation of the system [3, 4, 5, 6] or the design of the park which this paper is dealing with. The most recent references on this topic include [7], [8], [9], [10] and [11]. In [7], a methodology is introduced to perform the optimal sizing of an autonomous photovoltaic/wind system. In [8], the authors present a mathematical programming model to optimize the design of hybrid wind-PV systems that solves the location of the wind-PV generators and the design of the microgrids.

An overall power management strategy is designed for the system to coordinate the power flows among the different energy sources. Simulation studies have been carried out to verify the system performance using practical load profile and real weather data from Shiraz area in south-west Iran. It is to mention that there are many similar regions around the world with this typical situation that can be expanded. The paper is organized as follows: Firstly, the mathematical model of design of wind and solar systems developed. Secondly, an overall control strategy for power management among different energy is designed. Then the various algorithms are discussed the comparative study is carried then finally the optimal combination algorithm is proposed. In this article the genetic algorithm with LPSP technology, fuzzy C means clustering algorithm, intelligence evolutionary algorithm are appraised. The simulation results and conclusion are presented.

2.Literature Review:

A wind solar hybrid system consists of PV array, Wind turbine, battery bank, inverter, controller and other devices and cable. To satisfy the load demand PV array and wind turbine works together. Methodology for optimal sizing the wind /PV hybrid system was given by Borowy and Salmeh [12] that calculates the optimum size of a battery bank and the PV array for a hybrid system based on the minimum cost of the system using graphical construction technique. Based on Genetic algorithm technique optimum match designizing method for hybrid solar wind system was developed by Hongxing *et.al* [13]. Diafet *al* [14] presented a mathematical models for characterizing PV module, wind generator and battery considering various types and capacities of system devices and the configuration that meet the desired system reliability by changing the type and size of the devices system. Wang and Singh [15] presented the optimal design of an autonomous hybrid generating system including different power sources such as wind turbine generator, photovoltaic and storage batteries. A constrained mixed-integer multi objective particle swarm optimization (CMIMOPSO) algorithm was adopted to derive non dominated solutions for the optimal design. A probabilistic approach based on the convolution technique to assess the long term performance of a hybrid for both standalone and grid-linked applications was provided by Tina *et.al*. [16]. This approach uses energy index of reliability (EIR) directly related to energy expected to estimate energy performance of HSWPS for the reliability analysis. Yang and Burnett [17] used simulation model for analyzing the probability of power supply failure in hybrid photovoltaic wind power generation systems incorporating a storage battery bank and also analyzes the reliability of the systems, for the loss of power supply probability (LPSP) analysis.

3. Modelling of renewable sources and its Systems:

We have to design an energy system for a period spanning many years. The optimization model we propose focuses on one year which is decomposed in T time periods of one hour, where a time period t goes from time t- 1 to time t. Considering that the main part of the data depends on the climate, this allows to take into account the variations of weather during the year. As explained before, the types of wind turbines and PV panels that will be installed are predetermined. They are defined by their expected nominal output power, respectively E_t^w and E_t^p (in Kw.h) for each time period t, which are functions of the characteristics of the equipments, the land where they will be installed and the mean meteorological data over the past few years for each time period. The costs of a wind turbine and a PV panel are denoted by C_w and C_p respectively: these costs include purchase and installation costs (reduced to one year according to the lifetime of equipments) and annual maintenance cost including the lease of land.

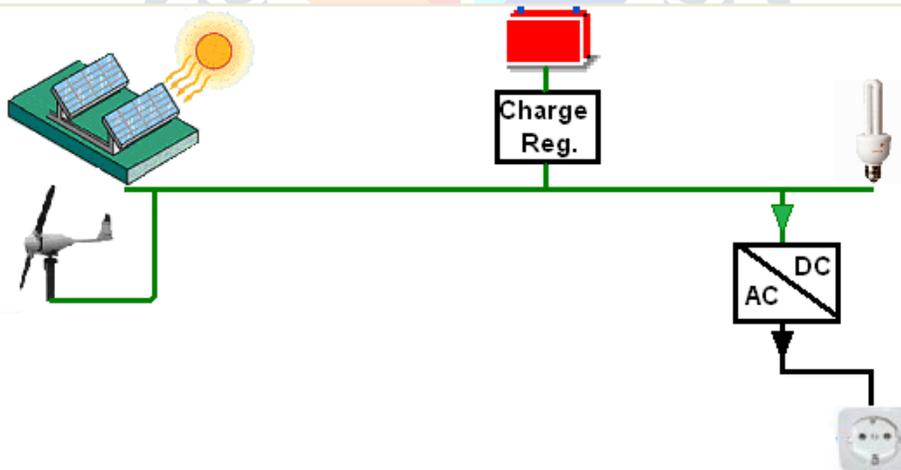


Figure.1.Hybride Renewable System

3.1. System PV Modeling:

As the operation and the performance of a PV generator is interested in its maximum power, the models describing the PV module's maximum power output behaviors are more practical for PV system assessment. In this paper, a mathematical model for estimating the power output of PV modules is used. The estimation is carried out using a computer program, which uses a subroutine for determining the power output of a PV module. Using the solar radiation available on the tilted surface, the ambient temperature and the manufacturer's data for the PV modules as model inputs, the power output of the PV generator (PPV) can be calculated according to the following equation [18]

$$P_{pv} = \eta_g N A_m G_t \quad (1)$$

where η_g is the instantaneous PV generator efficiency, A_m the area of a single module used in a system (m^2), G_t the global irradiance incident on the titled plane (W/m^2) and N is the number of modules used in system. All the energy

losses in a PV generator, including connection losses, wiring losses and other losses, are assumed to be zero. The instantaneous photovoltaic generator efficiency is represented by the following equation [19].

$$\eta_g = \eta_r \eta_{pt} [1 - \beta(T_c - T_r)] \quad (2)$$

where η_r is the PV generator reference efficiency, η_{pt} the efficiency of power tracking equipment, which is equal to 1 if a perfect maximum power point tracker is used, T_c the temperature of PV cell ($^{\circ}\text{C}$), T_r the PV cell reference temperature and β is the temperature coefficient of efficiency, ranging from 0.004 to 0.006 (per $^{\circ}\text{C}$).

3.2. System Wind Modeling:

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 η_{gg}) 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:

$$\text{Wind power} = (1/2) \rho A v^3 \quad (3)$$

3.3. Modeling of other System:

3.3.1. Battery Modeling:

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.

3.3.2. Power reliability model

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 (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.

Loss of power supply probability = Power failure time/T

where T is the number of hours in this study with hourly weather data input

4. 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.

Table: Economic analysis

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 θ_0 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

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 (%)	Inflation 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		

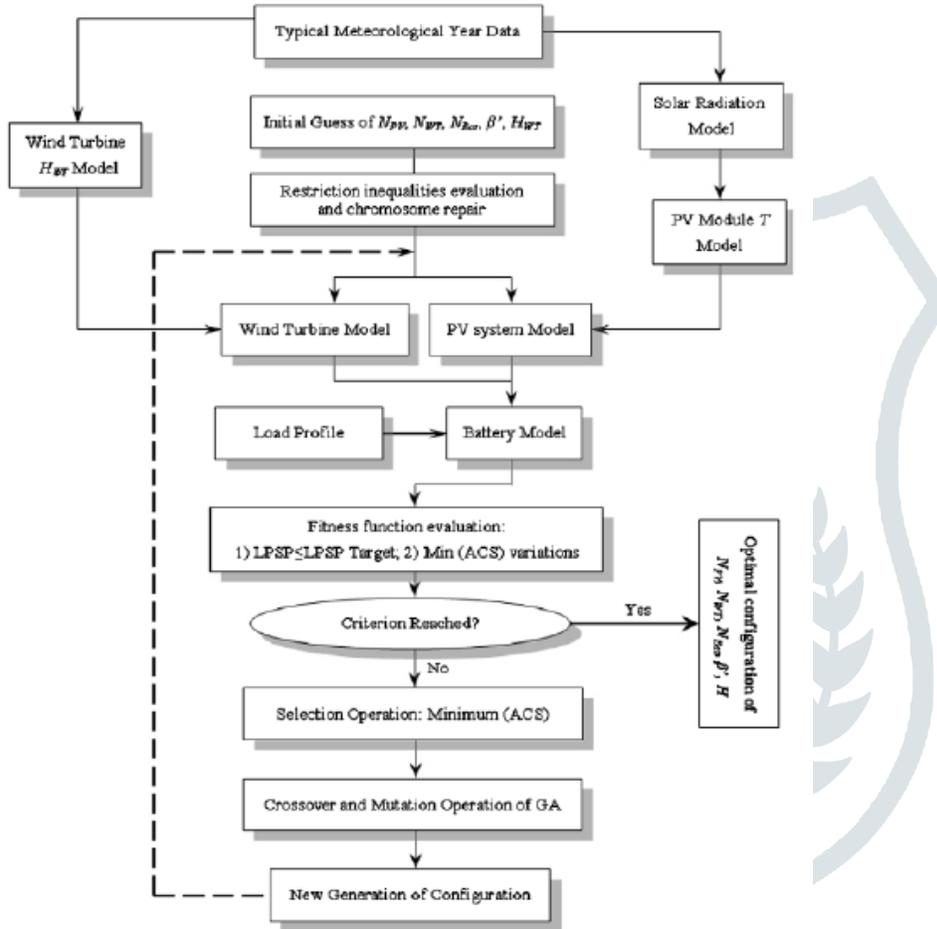


Figure 2 Optimal sizing of Autonomous Wind-PV hybrid system by Genetic Algorithm with LPSP technology

5.System optimization model with Fuzzy C -Means Clustering algorithm:

Objective Functions. In the proposed optimal sizing methodology of HPS, the main goal is to determine the amounts of each kind of DG. For a given system load, the objective can be set for the overall cost optimization.

$$\text{Min } CF(x) = \min \sum N_i C_{i,j} \tag{4}$$

where subscript *i* denotes the type of generations, namely, WT, PV, DG, and batteries, and *j* contains the cost of the unit, installation, and fuel consumption of the HPS. The fuel consumption of the DGs using fossil fuel is given with For the DGs using renewable energy resources like WG and PV, the operation cost can be ignored. For the DGs using fossil fuel, the operation cost should be accumulated in the studied period. The combustion of fossil fuel will contribute to the emission of CO2 and gaseous pollutants. The ramping characteristics of diesel generation are neglected in the article since the time resolution is set to be one hour. In (17), the fuel consumption cost *Cd* can be obtained.

$$f(P_d) = a + b \cdot P_d + c \cdot P_d^2. \tag{5}$$

$$C_{dsum}^{fuel} = C_d^{fuel}(P_d(c')) \times F(c') \times D(c') \times 8760, \tag{6}$$

where P_d can be obtained with the proposed power balance strategy

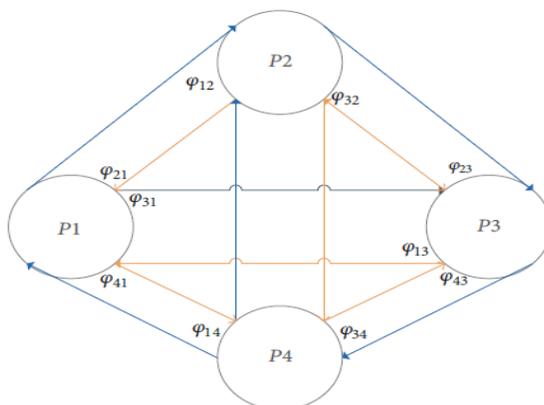


Figure .3. Four-state Markov model

5.System optimization model with intelligence Evolutionary algorithm:

Several approaches are used to achieve the optimal configurations of hybrid systems in terms of technical analysis. In this study, the technical sizing model for the HPFS is developed according to the concept of LPSP to evaluate the reliability of hybrid systems [20].

Three states may be appearing:

- a) The total power generated by the WG, PV and FC is greater than the power needed by the load, P_{inv} . In this case, the energy surplus is stored in the batteries and the new storage capacity is calculated using (10) until the full capacity is obtained. The remainder of the available power is dedicated to the electrolyser to produce hydrogen.
- b) The total WG, PV and FC power is less than the power needed by the load (P_{inv}), the energy deficit is covered by the storage and a new battery capacity is calculated using (21).
- c) In case of inverter input and total power equality, the storage capacity remains unchanged.

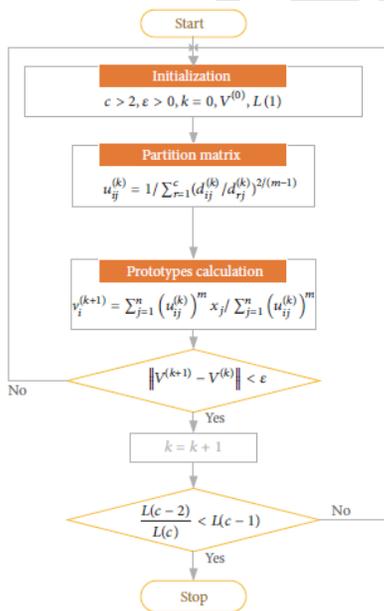


Figure.4. Self-adapted clustering procedure

6.Results and conclusions:

In this section, several simulations have been made by considering different combinations taking into account, the power of WG, PV and FC and the capacity storage. Technical and economic evaluation of hybrid systems with the proposed method has been studied with Shiraz weather data. According to the available weather data and the large number of variables of the optimization problem, in the most accurate mode, solar radiation, ambient temperature and wind speed can be modeled in the form of hourly curves. Monthly average of 20 years of Shiraz weather data (Table 2), with sample daily load profiles is used to simulation of proposed system. The estimated hourly load profile is shown in Figure 6. The load average in a day is 1(KW). It is worth mentioning that for modeling the load annual variation, 365 repetition of curve shown in Figure 6 is used.

Considering the different structure, the system simulation has been done. Then the simulation results are used to optimize the size of the system by GA and PSO. Convergence of the algorithms to obtain the optimum size of the system is shown in Figure 7. It can be seen that the fitness value decreases rapidly in the first 50 generations. During this stage, the GA and PSO concentrate mainly on finding feasible solutions to the problem. Then the value decreases slowly, and they have been converged approximately at the same point after 90 iterations. Consequently the total system cost has been similar in both PSO and GA. As mentioned before, the optimum size of the system obtained, when the lowest LCE is achieved. In exchange for lowest cost, there will be about 20% of the excess energy. It should be noted that the reduction in the amount of extra energy in the same system reliability conditions, Lead to increase LCE, thus economically is not affordable. The total cost of system performance in 20 years will be about 59042 \$.

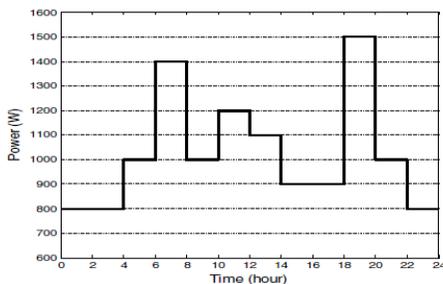


Figure5.Hourly load profile

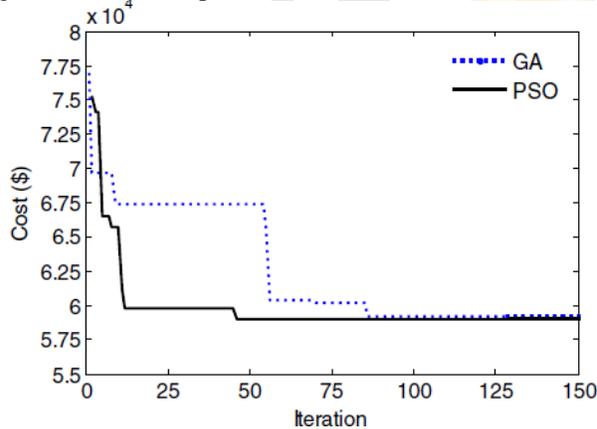


Figure5.Convergence process of GA and PSO to obtain the optimal solution

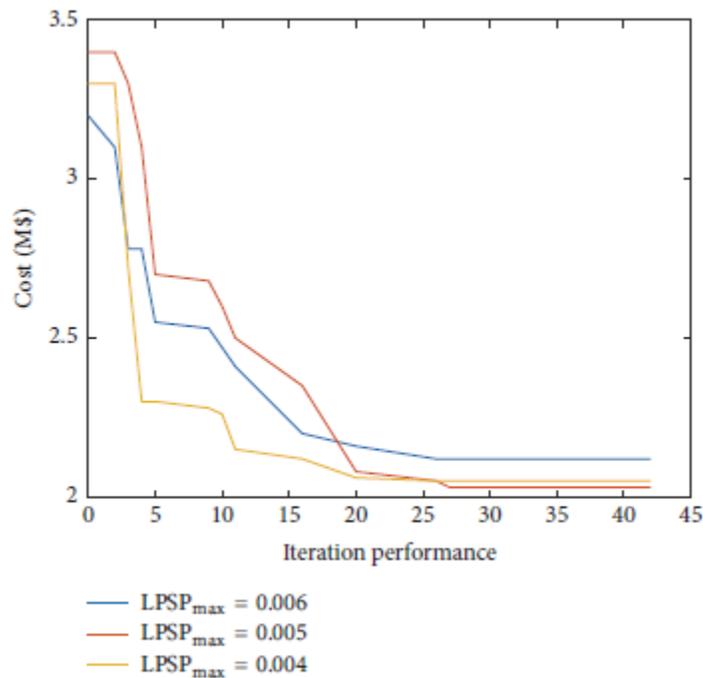


Figure. 6. Sensitivity analysis

In this paper, a novel method utilizing the self-adapted FCM clustering combined with the Markov model and GA is proposed to determine the best mix of HPS. A power balance strategy is also designed to guide the optimization process. The self-adapted FCM clustering can handle the stochastic characteristics of REGs, and the Markov model can significantly reduce the operational scenarios of REGs. The proposed method has comparable competitive overall cost, and it can be concluded that the benefits of the reduction of CO₂ and the improvement of LOSP are negatively related to the cost optimization procedure.

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