Optimal Sizing and Analysis of a Small Hybrid Power System for Medical University in Rural Area

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Abstract:

Consciousness of the need to reduce our unnatural weather changes and of the critical growth within the costs of traditional sources of energy has encouraged various nations to supply innovative energy strategies that spread renewable energy systems. For instance, solar, wind and hydro concerned energies are renewable energy sources, and they are environmentally friendly also and having broad use. It has become commanding for the Electrical engineers to find out for the renewable energy sources like sun, wind, ocean, geothermal and biomass as cost-effective, environment friendly and alternatives sustainable for conventional energy sources. However, at the time of non-availability of these renewable energy resources entire time during the year has led to research in the area of hybrid renewable energy systems. In last few years, lot of research has taken place in the area of the design, operation, optimization and control of the renewable hybrid energy systems. It is certainly evident that the area has vast scope. All of the load requirement conditions as compared with single usage can provide more economical and dependable electricity, also as environmentally friendly sources, by compounding such renewable energy sources using backup units to shape a hybrid scheme. Sizing the hybrid system elements optimally is one among the foremost important matters during this sort of hybrid system, which could sufficiently meet all of the load demands with a minor financial investment. the most aim of this paper is to seek out the cost-effectiveness of the hybrid system by using the 2 different optimization techniques. The optimal design model is developed during this paper, to style the hybrid generation systems with solar panels, turbine and battery banks and to supply the optimum system configuration. it's ensured that the annualized cost of the systems is minimized while satisfying the specified loss of power supply probability. A genetic algorithm is employed to seek out the optimum configuration. Moreover, four membership grades of the systems, just like the reliability, the economic efficiency, the complement and thus the environmental benefit, are created by a linearly-weighted fuzzy algorithm to seem at the configuration. The optimal algorithms are applied to a model of medical university and analysed the results, which shows that the complement and therefore the environmental benefit are taken full advantage of, and therefore the corresponding system cost is minimized with enough power supply reliability.

Keywords: renewable energy resources, design, optimization

1. Introduction:

Many rural areas within the world lack electrical supply due their remote locations and consequent high cost of electrical infrastructure. Worldwide, more than 1.5 billion people do not have access to electricity [1]. These communities have therefore resorted to the utilization of local methods to satisfy their lighting, heating, and cooking needs, which to a really large extent have a detrimental effect on the encompassing environment, economic development, and quality of life. Most times, these areas have abundant renewable energy resources like wind, solar, and hydro. in theory, these resources can provide electricity—at least partially. Renewable resources are intermittent in nature, which creates significant system design challenges [2, 3]. To mitigate uncertainty caused by renewable energy sources, the combination of conventional and renewable power generation known as a hybrid power system appears to be effective [4].Such systems can be either grid-connected or stand-alone and consist of conventional and renewable distributed generation, power conditioning equipment, and energy storage devices [5, 6]. This work focuses on the techno-economic feasibility of developing a hybrid power system to meet the electrical power needs of Medical University located in rural area of Maharashtra. Till date, from the literature reviewed on the renewable energy possibilities during this geographic area, the energy system proposed during this paper has never been considered and intrinsically are often considered to be novel with reference to the zone. Specifically, the work contributes to the subsequent:

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(i) Proposing a stand-alone hybrid renewable energy system to provide power to Medical University and a rural village in Maharashtra

(ii) Studying the feasibility of the proposed system to meet the electrical need of the community.

The proposed system is chosen to combine solar, conventional diesel generator, and battery storage with grid connection. The feasibility simulation is carried out on MATLAB software for optimum sizing and cost analysis of renewable energy systems. It is chosen as the best optimizing tool for the research as it is renowned for its ability to give accurate optimization results as it already contains a lot of information on the geographical area of interest.

1.1. System Deception:

The proposed hybrid power system consists of (a) a solar photovoltaic (PV) array, (b) a wind turbine, (c) diesel generator and (d) a at battery storage system. The diesel generator and the battery storage are intended to supply power when the solar power production is insufficient to meet the demand. The aim of the proposed system is to satisfy electricity needs of the medical university mainly by renewable energy sources with a very low dependence on the diesel generators. Combination of Solar ,Wind turbine with battery storage is the proposed design model for study.

The load profile of the village eff ectively remains similar throughout the year. A breakdown of the various types of electrical loads is tabulated in Table 1.

Table no. 1 Electrical Consumer in Medical university

Sr No	Installation	No.in University
1	Quarters	35
2	Hostels	8
3	School	1
4	Shops	6
5	Medical College (Department)	1(16)
6	Medical Hospital	1
7	Water Pump	11

The monthly consumption of each are shown in the figure 1. The hospital and hostels are consuming the more power as per the graph. The solar planned are installed in the hostels and the monitoring of the energy consumption done by the software developed by the company.

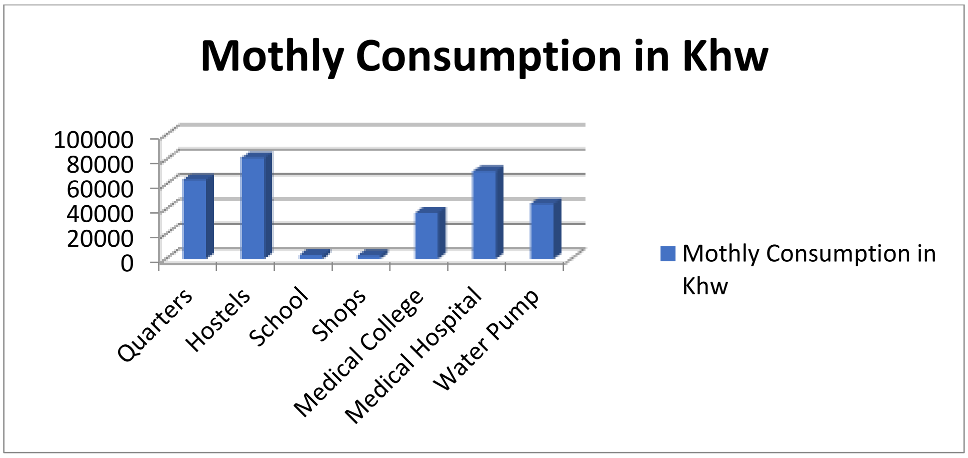

Figure 1: Monthly consumption in University

The total load per day (KWH/DAY) for various loads connected to HT transformer during the period 15th Dec to 31st Dec. collected and the average are calculated. The details of each hostel energy consumption are shown in figure 2.

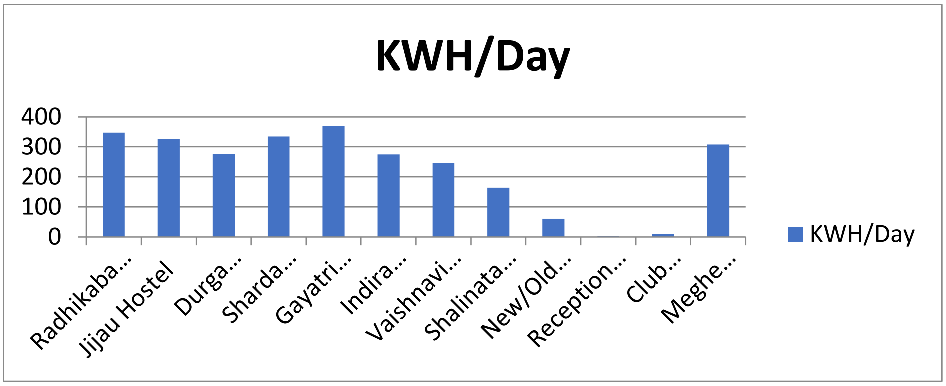

Figure 2: Daily consumption of each hostel

2 Models of Hybrid System Components and Battery

A hybrid wind- solar power generation system consists of PV arrays, wind turbines, battery banks, an inverter, a controller, cables and other accessory devices. If one wants to forecast the hybrid system performance, every component should be modeled and afterwards the generation system is regularly assessed to satisfy the load demand. In this, the models of 2 generation components of this system consisting wind turbines [5], and PV arrays are recommended [6]. Then, the output power at a given time are often calculated consistent with the weather data available.

The battery [7][8] can only be charged to rated capacity, and be limited by the utmost permissible depth of battery discharge when discharging. Therefore, modeling the charging-state of battery is important. At any time, the state of battery is claimed to the previous state of charge and to the energy production and consumption situation of the system during the time from t-1 to t [9]. During the charging process, when the entire output of the generation units, i.e. the PV modules, and therefore the wind generators, are greater than the load demand, the battery bank capacity available at time t are often described by

$$V_{bat}(t) = V_{bat}(t-1) - (1-\lambda) + \left(V_g(t) - V_L(t)/\eta_{\text{int}}\right)\eta_{\text{int}} \qquad (1)$$

where $V_{bat}(t)$) and $V_{bat}(t-1)$are the battery bank capacity available at time t and t-1, respectively, bat η is the battery efficiency, λ is the self-discharge rate of the battery bank, $V_g(t)$ is the energy generated by the generation units, $V_L(t)$is the load demand at time t, and η_{int} is the inverter efficiency.

On other side, at the time, load demand is higher than the energy generated, battery bank remains in discharging state. Hence, the battery bank capacity presented at time t may be expressed as

$$V_{bat}(t) = V_{bat}(t-1) - (1-\lambda) + (V_L(t)/\eta_{int} - V_g(t) -).\eta_{int} \quad (2)$$

At any time, the storage capacity is subject to the following constraints: Voltage of battery is always in between the V_{batmin} and V_{batmax}. where V_{batmax} and V_{batmin} are the maximum and minimum allowable storage capacity, respectively. V_{batmax} can be taken as the nominal storage capacity C_{batn}, and V_{batmin} can be given by

$$V_{bat\min} = DOD * C_{bat} \quad (3)$$

where DOD (%) represents the maximum allowable depth of battery discharge.

3.1 Power Reliability Model Based on LPSP Concept

LPSP [8, 9] is well-defined because the probability that an inadequate power supply results when the hybrid system, consisting the PV arrays, the wind turbines, the hydro turbines and thus the battery storage, is not able to keep the load demand. Values of LPSP range from 0 to 1. A LPSP of 0 means the load is typically satisfied, and a LPSP of 1 means the load isn't satisfied. LPSP are often expressed as in [10]

$$LPSP = \frac{\sum_{t=1}^{T} \left\{ V_L(t) - \left(V_g(t) + V_{bat}(t-1) - V_{bat\min} \right) \eta_{int} \right\}}{\sum_{t=1}^{T} V_L(t)} \quad (4)$$

where T is known as the operation time, in normal case T is one year. At the time LPSP is computed, the input data set comprises of hourly or daily solar radioactivity on a horizontal surface, the mean values of the ambient temperature, the load power demand during the year and the wind speed, the technical side specifications of the system components, and so on.

3.2 Economic Model depending on ACS Concept

ACS [11] is collection of the annualized capital cost C_{acap} and the associated annualized maintenance cost C_{amain}. Cost of the four main components requires to be considered, such as the wind turbines, the PV arrays, the battery and the other devices. Afterwards the ACS can be expressed as

$$ACS = C_{acap} + C_{amain} \quad (5)$$

Each component's annualized capital cost takes into account the installation cost, and is calculated by

$$C_{acap} = C_{cap} \frac{i.(i+1)^{Y_{proj}}}{(i+1)^{Y_{proj}} - 1} \quad (6)$$

where C_{cap} is the primary capital cost of each component, Y_{proj} is considered as the component lifetime, i is considered as the annual real interest rate. The lifetime value Y_{proj} of few devices can be taken from [12].

The annualized maintenance cost can be estimated by two different ways. First, under normal conditions, cost of maintenance of wind turbines during service life is 15% to 20% of the total/overall cost, while the PV module is

10%, & the battery is also 10%. Next, it can also be deliberated to be a static value which normally depends on practical statistics.

4 System Optimization

The hybrid system alongside backup/storage devices are often connected within the stand-alone or within the grid connected mode. Both these modes require an accurate choice and sizing of the system components to supply the demand continuously mandating reduced cost and increased reliability.[10] So, an attempt is made during this paper to urge the optimal sizing of a hybrid system constituting wind and PV combination with battery banks characterized by two objectives like Loss of Power Supply Probability (LPSP) and Genetic Algorithm (GA). The system connected to a sample load is analysed with the weather and other parameter as per requirement

4.1 Model with Genetic algorithm

A program was advanced to simulate operation of this PV hybrid system. Genetic algorithm was used to adjust the sizes of this hybrid system components. The prices of this pollutant emissions were considered with the optimization. It is cost effective in remote areas with the help of such hybrid systems. Elementary flow chart of GA is shown within the figure 3

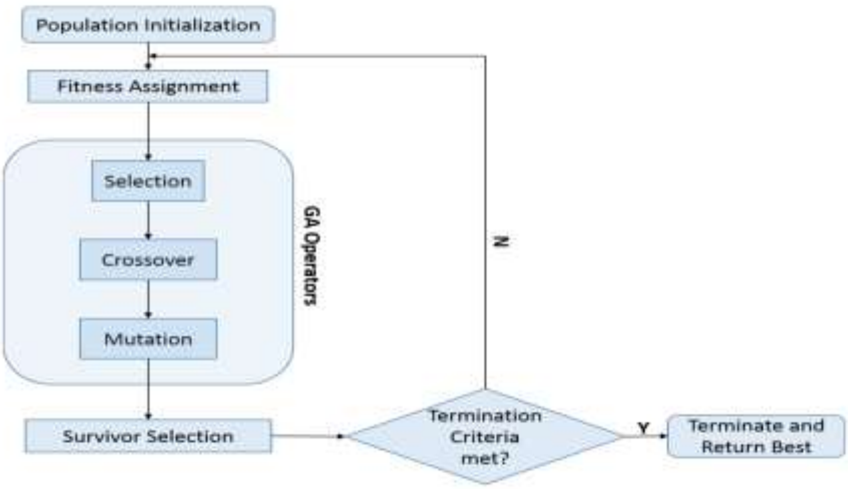

Figure 3 Flow chart of GA for proposed Hybrid system

Initial guess of P_W,P_{pv}, C_{bat}, and Weather data monthly data used for the designing the hybrid generation model system. The Fitness function used as LPSP AND ACS by using conditional expression. Selection operation as min. ACS, Crossover and mutation of GA applied as shown in the flow chart in figure 3, after that new generation of configuration.

The decision variables in this optimization process is known as the wind turbine power PW, the PV module power P_{PV} and the battery capacity C_{bat}. Hourly basis daily weather data of typical year includes the solar radiation on the horizontal surface, wind speed and so on. Combining this ACS with this LPSP depend on a penalty function, this fitness function which can be expressed as

$$F_{fotness} = ACS + M.[\max(0, LPSP - 0.5\%)]^2 \qquad (7)$$

where M is considered as penalty factor.

The power outputs of this generation units are being calculated by using their specifications also due to the weather data. The system configuration is afterward optimized by engaging the genetic algorithm, which dynamically pursuits for the optimal configuration to attenuate the fitness function. for each system configuration, LPSP of the system is examined to measure whether the necessity, i.e. LPSP target, are often satisfied. Then, the configuration of smaller fitness is subjected to the next crossover and mutation operations of

GA so on supply subsequent generation population until the criterion is satisfied. The optimal configuration can finally be found by achieving the lowest ACS while satisfying the LPSP requirement.

4.2 Linearly-Weighted Fuzzy Algorithm Model

The system optimization model supported linearly-weighted fuzzy algorithm [13] considers three optimization objectives: the reliability, the value efficiency, the complement and therefore the environmental benefit. Each configuration has four membership grades consistent with the four objectives:

$$x = (x_0, x_1, x_2, x_3) \quad (8)$$

Various users have varied requirements to the four objectives, so the set of weight is created:

$$Z = (z_0, z_1, z_2, z_3) \quad (9)$$

Thus, this objective function is being expressed as

$$\min\ f = (x_0(z_0) + x_1(z_1), + x_2(z_2), + x_3(z_3)) \quad (10)$$

When the target function is minimized, the optimal configuration is found. The membership grade of reliability is that the same because the LPSP, and therefore the membership grade of environmental benefit is proposed.

4.2.1 Different membership model

In [14] the varied methods are discussed intimately. Analyzing the varied formula, different grade model is used here during this paper like grade model of economy and model of complementary. the planning of both the models are discussed here

Grade model of Economy

Based on this ACS model, this cost per kWh of this hybrid generation system may be expressed as

$$C_{kwh} = \frac{ACS}{E_{year}} \quad (11)$$

Where C_{kwh} is considered the power generation system cost per kWh, E_{year} is considered the annual energy production of this hybrid generation system.

The membership grade function of the economy is:

$$\mu_1 = 1 - \frac{C_{kwh}}{C_{acap}} \quad (12)$$

where C_{acap} is maximum cost per kWh acceptable to users.

b) Model of Complementary

The complementary of the hybrid system is measured by the difference in magnitude between the facility consumption needed by the load and therefore the total energy production generated by the generation units. The membership grade function of the complement are often expressed as

$$\mu_3 = \frac{\min(E_{year,} E_{yearL})}{E_{year} + E_{yearL}} \quad (13)$$

where E_{yearL} is considered the total load power consumption for one year.

5 Analysis of Result

The figure 4 shows the graphical representation of the Hourly, Daily and Monthly graphs. during this we will see the consumption of the hostel energy on the idea of the monthly, daily and hourly. It helps to analysis of energy used. It shows the worth important, Export and Net value in Kwh. There are different graphs for various energy consumption depends on their used. the info available are wont to design the system model.

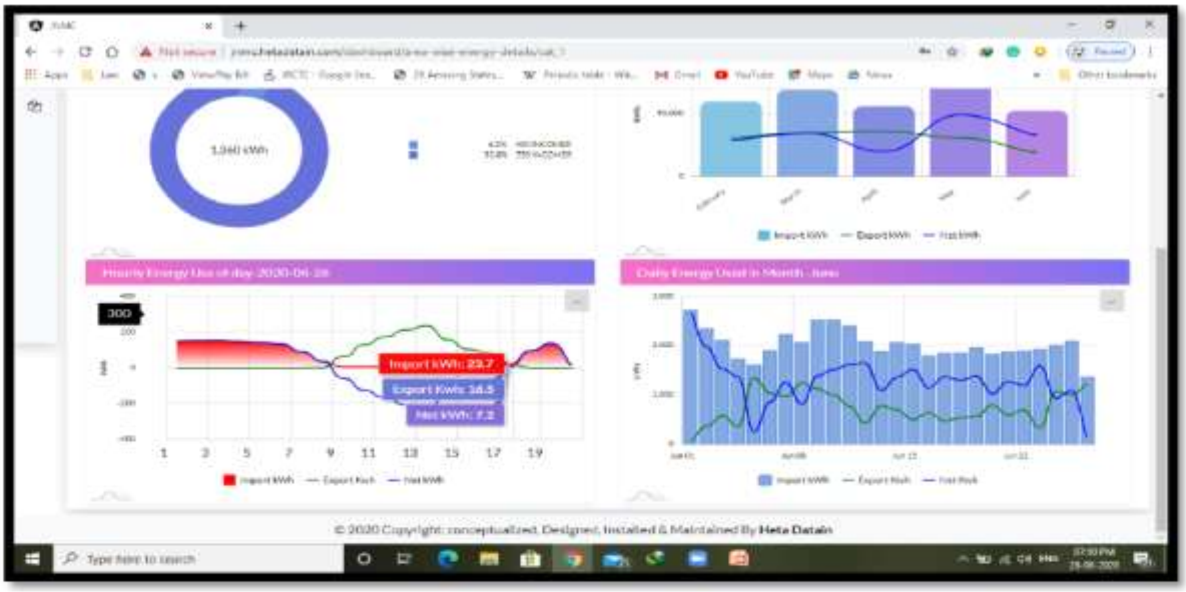

Figure 4. Hourly, Daily and Monthly Graphs

Sensitivity Analysis.

In this energy report there are different color used for the varied hostel. And it shows this monthly consumption of the hostels as per their color. this speed of the consumption is different of varied hostels variety of them consume more energy and a couple of consume less energy as per their need on monthly basis and within this right-hand side the graph shows this yellow line for 400 KW Incomer consumption and Brown for 750 KW consumption on this monthly basis.

The proposed methods are applied to style one demonstration project, which is formed to supply power for a medical university during a foreign village of a county, India. This village is centered at 20.745′ north latitude and 78.602′ east longitude, in between of 378 m above water level. At this measured site, the effective wind power density is low, this standard annual wind speed is 2.73 m/s, the standard annual radiation is 4845.6 MJ/m2. supported this models of this hybrid wind- solar generation systems developed during this paper, this optimal configuration of the system fulfilling the requirements is acknowledged. The calculation results are shown in Table 2, where method 2 is that the algorithm supported GA, and method 1 is that the algorithm supported the linearly-weighted fuzzy algorithm.

Table 2 Results Optimization Sizing

Components	Result by fuzzy algorithm	Result by GA
Solar Power (W)	25*9	350
Wind Power	50*2	125.3
Battery	80*4	380
LPSP in %	0.324	0.368
ACS in Rs (India)	69 Lacs	78 Lacs

The design of the hybrid generation system isn't simply a mixture of wind and solar generation units. so as to form the foremost efficient use of energy resources and save investment, optimal methods in consideration of complementary characteristic among wind energy, solar power with utility grid should be wont to find a scientific and reasonable configuration of every unit. At an equivalent time, A battery bank is completely necessary to make sure system power reliability. Without it, the load demand can hardly be met continually.

The LPSP concept utilized during this study could also be a statistical parameter decided by users. it's clear that higher power reliable systems are costlier than lower requirement systems. A smaller LPSP, i.e. higher reliability of the systems, results in high cost of the system and therefore the other way around. Choosing an optimal system configuration according to the system power reliability requirement can save investment and avoid blind capital spending.

6 Conclusions

The optimum design sizing methods for the hybrid wind- solar systems supported on the genetic algorithm and therefore the linearly-weighted fuzzy algorithm is essentially developed. the 2 methods are often utilized to seek out the system optimum configuration which may attain the specified LPSP with lowest annualized cost of system. Taking about the wants of the users and environmental benefit into consideration, the model which is predicated on linearly-weighted fuzzy algorithm, is more adaptive to different designing condition. The proposed methods during this paper are applied to style an indication project of the hybrid wind- -solar system. With the assistance of daily measured field data of this studied project in one year, the energy contribution of the generation units, the battery working state and therefore the energy balance of the system has been investigated. the higher complementary characteristic among wind energy and solar power has been acknowledged during this paper. The generation of the wind energy isn't existing up to the mark during this region during all months of the year. The wind energy is essentially available for less than four months during the season, by considering this condition during this method of linearly-weighted fuzzy algorithm, cost effective.

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