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Optimization and design of wind and solar hybrid system with battery storage using the PSO algorithm considering the economic constraints (Case Study in Ardabil province)

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ABSTRACT

Wind and photovoltaic systems due to the possibility of direct conversion of solar and wind energy to electrical energy is one of the most common applications of renewable energy that are considered .this article aims improving load factor in specific areas, using the PSO algorithm The use of hybrid systems connected to the network. In order to evaluate the performance of the proposed algorithm, a sample study in Ardabil province was conducted on a sample of residential posts. Target Feasibility of a photovoltaic system - connected wind to determine the optimal capacity of the battery and the optimal size and number of wind turbines to supply part of the time mail is checked so that the load factor load curve and the curve finally post on Optimal be corrected. Simulation results PV system - grid connected wind-powered battery backup in load factor correction curve shows the usage of this post intended to reduce peak load and minimize the total cost of production during the life system, which uses the PSO algorithm with constriction factor determining the optimal size of these resources and minimize the cost function and efficiency of the system in different conditions of performance real-time information and be examined Ardabil Meteorological .The results, confirmed the validity of the proposed model.

Keywords: *Optimization, Hybrid Wind-Solar, Load Factor modification, Storage Batteries, PSO.*

INTRODUCTION

Buildings play an important role in consuming existing networks' energy. For instance, more than one-third of energy consumption and more than Two-thirds of electrical energy in America is related to this section. So energy management in buildings is an important issue for engineers and power system researchers. According to the economic and environmental aspects, it's necessary to use new technologies. But when we use different energy sources simultaneously, due to the uncertainties related to the performance of each of these sectors, we face some problems which can be removed using an intelligent energy management system. Many of these systems had been introduced in the literature. Some of the articles are arranged for planning manufacturing sector. In the second article, a plan has been introduced to exploit4 distributed generation technologies to use at home with the aim of increasing consumer interest. In the third article, the problem of energy management in a low-energy building is solved using uncertain and certain models. The fifth article introduces a home management system with a focus on cost control home appliances with the aim of minimizing household energy consumption considering the well-being of residents. Also the seventh article presents a two-stage algorithm to use the home appliances that its basis is the least payment for the consumer and the residents' comfort. These articles confirm the positive impact of demand response programs in reducing costs.

Use of renewable energy resources in health centers helps to reduce traditional energy consumption and causes access to a low-carbon economy. For this reason, in the past decades and around the world we have observed rapid developments in the use of renewable energy in these centers and buildings. In this regard and in order to achieve efficient hospitals and in accordance with international standards, some researches were conducted in which saving energy and reducing pollution have been considered as strategies for sustainable development of medical centers. Some limited studies have been arranged in order to determine the number of required renewable resources for energy planning in hospitals. For example the 11th article in which due to uncertainty in demand and prices for electricity, the Monte Carlo simulation is also being used. In another study, a systematic approach is provided to proper selection and identify the best option for reconstruction of existing buildings in hospitals.

Several energy sources including photovoltaic systems, wind power plants, diesel generators, gas turbines and micro turbines in combination with each other can form a hybrid energy system. Despite these resources, single solar cells and wind power plants in remote areas are widely used in feeding electrical charge. These systems are usually combined together because their characteristics are almost complementary to each other. Due to the cleanliness and being renewable of these energies, organizations and several countries are interested in using it and doing extensive research in this direction. Various methods for optimal design and to minimize the costs of wind and solar power plants have been proposed. The combination of linear and non-linear programming are presented based on partial analytical and numerical calculations in [13]. In [14] a method based on nonlinear programming is provided to choose the size and location of wind farms connected to the grid based on different scenarios that its aim is to reduce costs and maximize energy in square meters. In [15], an iterative search algorithm has been used to find the optimal size of a hybrid solar -wind system with storage batteries. In some papers, energy storage is considered in distributed generation systems. A genetic algorithm has been used to determine the size of an optimal solar- wind complex powerhouse. Mr. Asghari and Ameri have done economic feasibility for hybrid systems, diesel and photovoltaic with the battery storage. And the same group [3] examined the optimal sizing of a hybrid wind-solar system network-independent. Roy [4] a method based on nonlinear programming is provided to choose the size and location of wind farms connected to the grid based on different scenarios that its aim is to reduce costs and maximize energy in square meters. Kellog and Nahrin have sedan iterative search algorithm to find the optimal size of a hybrid solar –wind system with storage batteries .Kvtrvlyz and Klvkvtsa [7] have used a genetic algorithm to determine the size of an optimal solar- wind complex powerhouse.

2. The objective function

According to the discontinuous characteristic of wind as well as solar radiation and their high dependence on weather conditions, the most important debate is to design are liable system for power supply. In this way, paying attention to the cost of the system is inevitable, therefore optimum hybrid system is designed to reduce peak load times and increase reliability of the network .In the system under study, wind turbines, PV panels and battery capacity should optimally be determined. For this purpose, the PSO algorithm is used because it can compute the cost of all system components according to their function and in acceptable modes. In the proposed method, the algorithm output is wind turbines, photovoltaic panels and batteries. This number must be optimized in such a way that not only supply energy but also minimize the system's 20-year costs. System's cost includes the cost of purchase and installation, maintenance and repair of components during 20 years. Operation of the system is calculated from the following equation:

$$C_i = N_i[Ccost_i + RCcost_i \times K_i + O\&Mcost_i] \quad = WG, PV, Battery \tag{1}$$

In which Niis the number or size of equipment,$Ccost_i$is the initial investment includes the cost of purchase and installation, $RCcost_i$ is the placement price, $K_i$is the placement of system performance in 20 years, O&M costi is the cost of operation and maintenance of the system in 20 years.

The objective function that should be minimized is the total cost of system operation. It is expressed as follows:

$$C_{system} = C_{WG} + C_{PV} + C_{BAT} + PF \tag{2}$$

$$N_{PV} = Integer \quad , \quad 0 \le N_{PV} \le N_{PV}^{max} \tag{3}$$

$$N_{WG} = Integer \quad , \quad 0 \le N_{WG} \le N_{WG}^{max} \tag{4}$$

$$N_{Bat} = Integer \quad , \quad 0 \le N_{Bat} \le N_{Bat}^{max} \tag{5}$$

$$P_{Supply} \ge P_{Demand} \tag{6}$$

$$P_{b\,min} \le P_b \le P_{b\,max} \tag{7}$$

$$P_{b\,min} == (1 - DOD).\ P_{b\,max} \tag{8}$$

3. Dimensions and function of the hybrid system

The purpose of this section is to establish the relationship between production and consumption of hybrid systems for better utilization of domestic load to reduce peak load. In this regard, the dimensioning systems for electricity production and optimizing the efficiency and reliability are economically essential. So the differences in productivity PGen should minimize from renewable energy and demand times in this way:

$$\Delta P = P_{Gen} - P_{Load} \tag{9}$$

The system block diagram is shown in Figure 1. In this system, WG and PV are used as used as a source of energy storage. In Figure 1, the output unit is connected to a DC. The number of batteries are connected to the box as a storage system. Lead-acid batteries store the produced energy by PV and WG system S and at the time of peak load they enter it to the system to improve the load curve. The Saved energy is transferred to the consumer by the DC / AC converter. In order to optimally design and energy management, as well as view system performance under various conditions, having enough information about the structure of each component is essential. The system consists of a number of wind turbines, photo voltaic, batteries and converters. Each of these components are reviewed in this section.

4. Wind Turbine

The first wind turbine that converts wind energy into mechanical energy and mechanical energy is converted into electrical energy by the generator [10, 11]. In Figure 2 the turbine power output versus wind speed is drawn. Find the power output of the turbine by turbine wind speeds after a certain amount of proven and for speeds greater than the maximum speed, the turbine stops. The power output of the wind turbine is calculated from the following equation.

$$P_{WG=} \begin{cases} 0 & V_w \le V_c\,, V_w \ge V_F \\ P_R \times \left(\dfrac{V_W - V_C}{V_R - V_C}\right)^3 & V_c \le V_W \le V_R \\ P_R & V_c \le V_W \le V_R \end{cases} \tag{10}$$

P_{WG} power output of the wind turbine, P_R rated power per turbine, V_W wind speed, V_C quickly cut down, V_F high cutting speed and V_R turbine is rated speed. Other features and parameters used in the model wind turbine is shown in

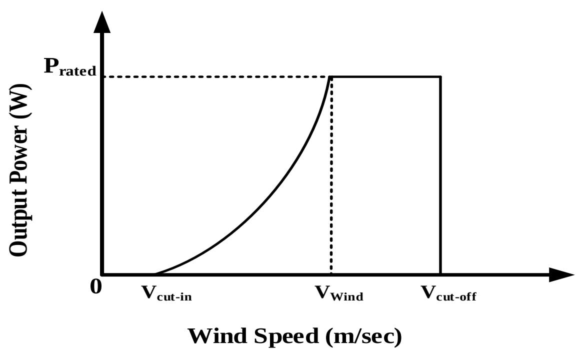

Figure 2. Turbine power output versus wind speed

Table 1. Technical Specifications studied wind turbine

1KW	Rated power
2.5 m/s	Quickly cut down
11m/s	Rated speed
24m/s	High-speed cut
2506 €	The initial capital cost
25/06 €/year	Maintenance and performance
20 year	life span

5. Photovoltaic panel

Photovoltaic systems process the sun's energy directly into electrical energy is converted. In photovoltaic technology, the semiconductor cells which have a large p-n diodes, are used. This means that the light onto each cell, and direct current voltage is generated. Several cells are combined to produce a module to provide current and voltage. PV production capacity Azmadlh given by [13,14]

$$P_{pv} = \frac{G}{1000} \times P_{pv,rated} \times \eta_{MPPT} \tag{11}$$

In this regard GG radiation in watts per square meter, $P_{(pv,\ rated)}$ rated power each photovoltaic panel and η_{MPPT} efficiency DC / DC converter is a photovoltaic panel. The concept of following MPPT maximum power point that makes the most power and solar energy harvesting module is in different weather conditions. The effect of temperature on the surface of the PV panel is neglected. Other features and parameters of photovoltaic panels used in the model are shown in Table 2. [8].

Table 2. Technical Specifications solar modules

110W	Rated power
17V	Voltage at Pmax
6.47 A	During the Pmax
21V	Open circuit voltage (Voc)
7.22A	Short circuit current (I_{SC})
519.14 €	The initial capital cost
5.19 €/year	Maintenance and performance
20 year	life span

6. Battery and converters

Chosen for the simulation of lead-acid batteries, which have high efficiency, low cost and low self-discharge compared with its variety [15]. According to charging or discharging the battery Input power can be positive or negative. State of charge (SOC) battery, according to the calculations of productivity and disposable, it is obtained:

1) If $P_{PW}(t) + P_{PV}(t) = P_L(t)$ when the battery capacity remains unchanged.
2) If$P_{PW}(t) + P_{PV}(t) > P_L(t)$, then the surplus power produced hybrid system used to charge the battery bank and new capacity battery can be obtained from the following equation.

$$P_b(t) = P_b(t-1) + [P_z(t) - P_l(t)/\eta_{inv}]/\eta_{bf} \quad (12)$$

Consultants for better utilization of $P_{PW}(t) + P_{PV}(t) < P_L(t)$ are discharged battery. The rated capacity of the battery bank is discharged only allowed to a limited extent. The maximum allowable depth of discharge (DOD) by the beginning of system design and optimization process is determined. In this case the new capacity battery can be obtained from the following equation [9].

$$P_b(t) = P_b(t-1) + [P_l(t)/\eta_{inv} - P_z(t)]/\eta_{bf} \quad (13)$$

In this regard, $P_b(t)$ و $P_b(t-1)$ at time t and t-1 is the battery capacity. $P_z(t)$ be a series production hybrid system and $P_l(t)$ is the required time at the moment. Recharge efficiency inverter efficiency is η_{bf} and η_{inv} respectively. Other features and parameters used in the modeling batteries and converters in Tables 3 and 4 are shown [9].

Table 3. Battery Case study

Battery	
230Ah	Rated capacity
12V	Rated voltage
80%	DOD
100%	Efficiency charging time
95%	Efficiency, discharge time
264€	The initial capital cost
2.64 €/year	Maintenance and performance
3 year	Working life

Table 4. Profile converters studied

Converter	
1500 W	Rated power
80%	Output
1942 €	The initial capital cost
19.4 €/year	Maintenance fee
4.5 year	Working life

7. PSO algorithm

The algorithm is composed of two parts.the battery in the first part of the algorithm using direct search method is determined. The algorithm starts entering data relating to the annual and radiation data in the region and also costs related to photovoltaic systems, network, battery backup and a wind turbine, turn to choose the optimal number of battery reaches, at this stage ofthe combinations specified capacity of the battery set, as the number of battery optimization for the objective function to be selected. In other words, the amount of power produced by photovoltaic-wind system, monthly and annual peak load to the post, after the effect of PV and wind turbine systems for each of the selection process, the number of batteries, the system calculates PV and wind turbine is. The output of this algorithm to determine the optimal number of battery based on the PSO algorithm to optimize the objective function is shown in Figure 3.

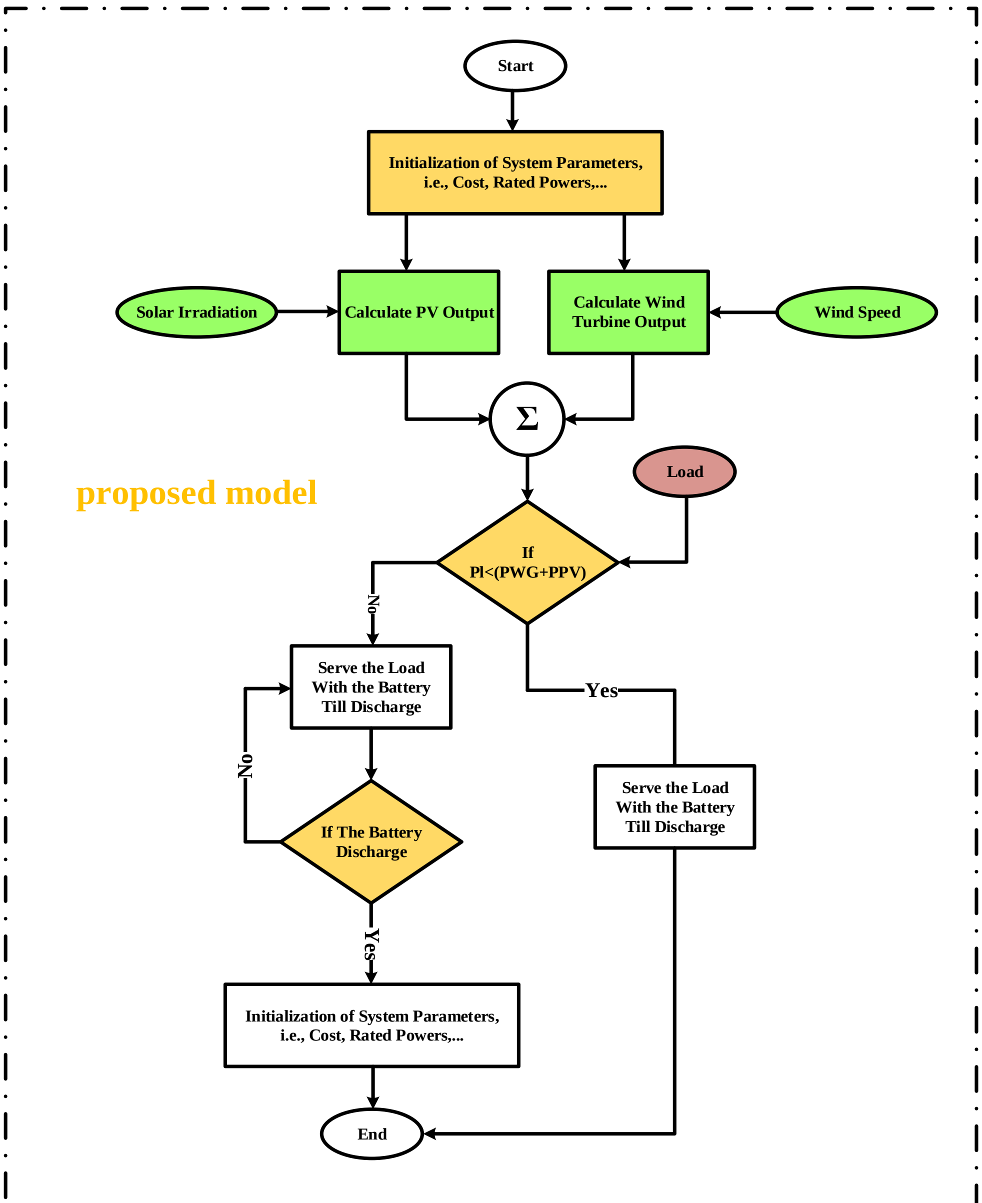

Figure 3. The hybrid system control flowchart

8. Studies

Figures 4 and 5 radiation and wind speed charts a day in the spring show in Ardabil province.

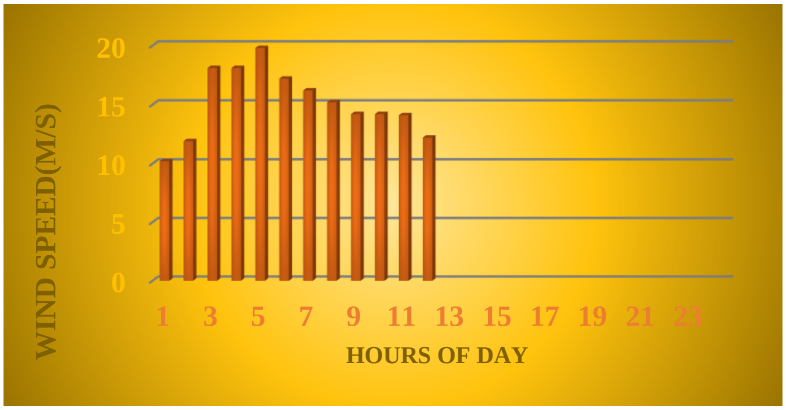

Figure 4. The intensity of wind (m / s)

Figure 5. Radiation charts

9. E-residential study

Simulation on electrical load is variable for a sample post was residential. Figure 6 hybrid system in the production process as well as in Figure 7, the charging and discharging of batteries specified.

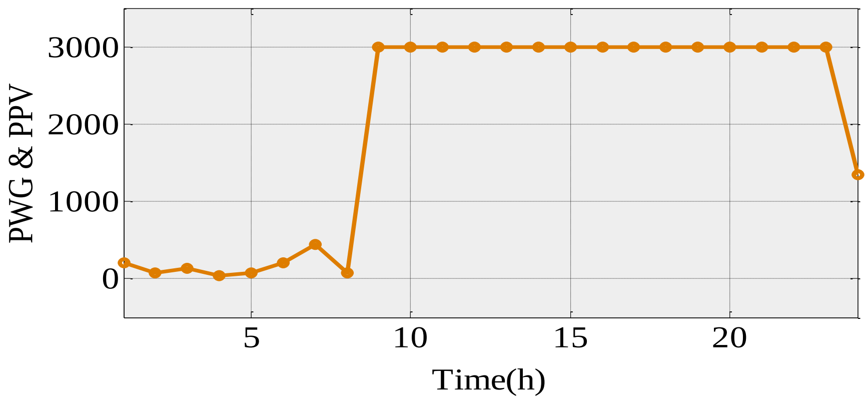

Figure 6. The production and storage of hybrid systems in residential Posts

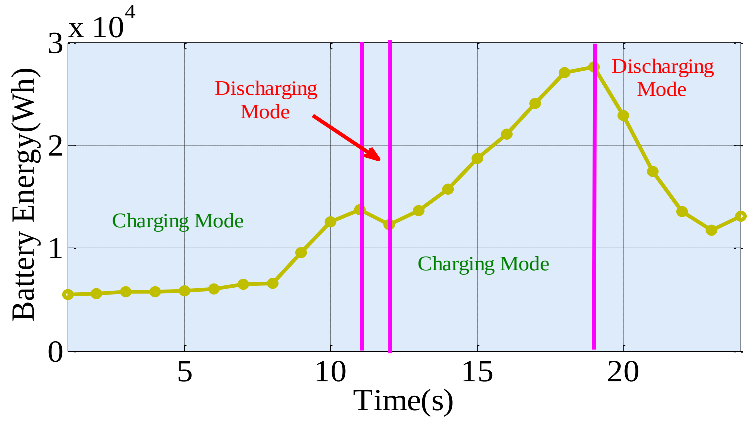

Figure 7. Changing the battery in a day and residential Posts

In Figure 8, the process of generating and storing energy in the battery is shown As can be seen until 11 System battery is being charged at 12 due to increased disposable and lack of sufficient energy produced by the hybrid system battery is 12 to 19 hours becomes discharger's charging is the hours, 19 due to the increased usage comes the battery is discharged.

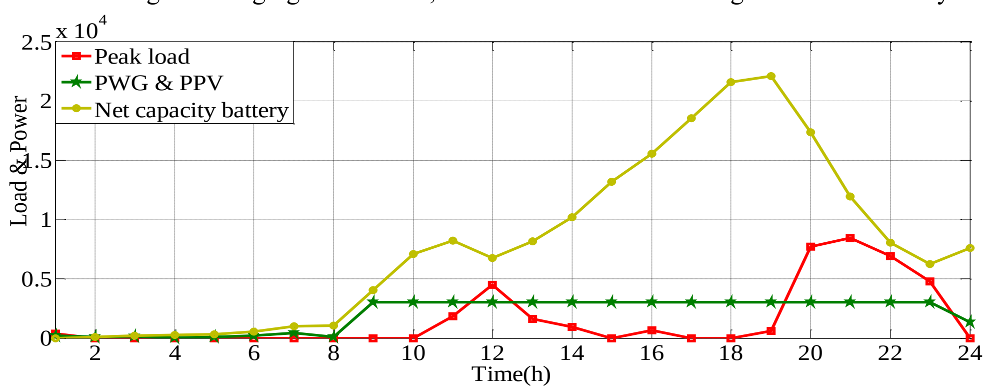

Figure 8. The process of production and energy storage in residential Posts

The process of reducing errors and find the optimal point by PSO algorithm is shown in Figure 9

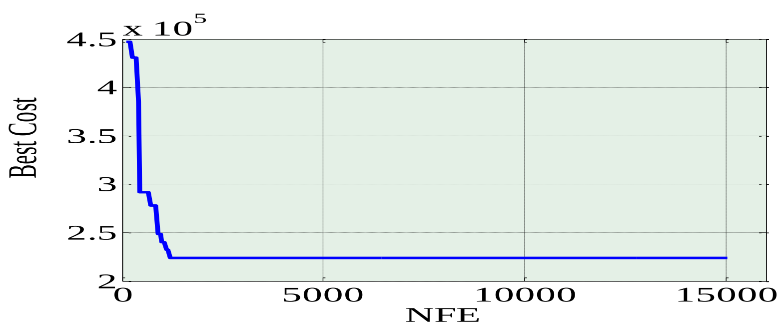

Figure 9. The process of reducing the cost of the PSO algorithm in residential Posts

The results of the algorithms PSO, ICA, GA is shown in Table 5. As can be seen, as well as the simulation results of the PSO algorithm is better than other algorithms.

Table 5. Results of Particle Swarm Optimization algorithm competitive in the post-colonial building

Description	Cost	Parameter optimization			Time (S)	The number of repetitions	Number or Country	Optimization methods
		N_{WG}	N_{PV}	N_{bat}				
C_1=2 C_2=2	2.56×10^5	3	0	10	1007	300	45	PSO
number of imperialists=18 percentage colonial revolution= 0.2	2.92×10^5	5	3	7	1156	300	45	ICA
$P_m = 0.7$ $P_c = 0.3$	2.81×10^5	4	2	13	1198	300	45	GA

CONCLUSION

Simulation results show that the PSO algorithm-based simulations using different input variables can be optimized by having the output based on selected inputs. It was observed a significant effect on improving the efficiency of photovoltaic systems, wind load and peak load curve is decreasing. As was observed optimum use of the system load curve patterns and indicators in posts to improve the load factor. Posts studied the changes in load factor to the number of batteries, the power output of a photovoltaic system and wind-load consumption pattern (type E) depends. The amount of change in the load factor correction, the economic and technical viewpoints will vary. But in some cases according to studies (especially residential Posts), the installation of photovoltaic-wind load coefficient in changing viewpoints of both is the same.

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