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Optimization and Sizing of a Hybrid Solar-Wind-Battery-Gasoline-Diesel System for Emission Reduction and System Stability

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Abstract:
A hybrid Solar, Wind, Battery, Gasoline and Diesel System Optimization Sizing (HSWBGDSO) model is proposed to optimize the capacity sizes of the renewable energy resources integration based on battery bank, gasoline and diesel system. The optimal renewable energy size could be reached based on the proposed constraints and the renewable energy resources availability as well as the system requirements. A cased study is discussed based on a proposed flowchart. Different scenarios of hybrid models are studied to reduce the fossil fuel emissions. Using the battery bank is playing a crucial rule for system stability due to the fluctuation of the renewables. Results show that the fossil fuel emission is reduced to 617.4 pounds which is representing 33.33 % of the original emission value.

Keywords: Economic dispatch, Solar Irradiation, Wind Speed

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INTRODUCTION

Economic dispatch is defined as the short-term identifying factor of the optimal output for multiple energy sources. The most important objective of the economic dispatch problem is the scheduling of the energy sources output to meet the demand using the least operating cost while the optimal unit output satisfies the agreed upon system constraints and requirements. Several scheduling methods have been used to achieve this goal. [1] applied Bat algorithm to solve the economic dispatch problem of standard six generators. Transmission losses have been considered in this problem. Bat algorithm's results were compared to conventional quadratic programming (QP) and Genetic Algorithm (GA). Ribeiro et al. confirmed that Bat algorithm is a powerful method in solving difficult problems in power systems. In [2], Ant Colony Search Algorithm (ACSA) technique was used for solving the economic load dispatch problem. The algorithm has been implemented in MATLAB software and then they applied to Egbin Thermal Power Station in Nigeria. The results were compared with Lambda method where Ant Colony overcome Lambda method in addressing operating cost and power loss problem. Vortex search algorithm (VSA) was applied to solve six generators power system economic dispatch problem. The economic dispatch problem constraints are transmission line losses, valve point loading effect, ramp rate limits and prohibited zones [3]. Results of running Vortex search algorithm were compared with PSO, CPSO, WIPSO, MFO, GA and MRPSO techniques where they found that Vortex search algorithm outperform the mentioned techniques. Sola et al. investigated the key factors affecting energy management in industries, considering economic, contingency, technological change, and behavioral perspectives. Their findings revealed a positive correlation was observed among all the factors identified. Statistical tests showed that the factors could not be explained on their own. Hypothesis tests were used to confirm the effect of the factors on the groups surveyed [4]. Musbah proposed a new methodology for forecasting energy plans in hybrid energy systems that encompass both renewable and conventional sources. They employed classification machine learning models and evaluated the performance of these models using a confusion matrix [5] [6]. Table (1) shows different studies used different method to solve economic dispatch problem.

In this paper the scheduling of a hybrid energy system consists of two traditional energy sources (diesel and gasoline) and two renewable energy sources (wind and solar) are studied for autonomous areas. The input values of these sources were weakly diesel and gasoline price data, hourly wind speed and solar irradiation. The scheduling of this hybrid system is based on the availability of renewable energy sources and the price of diesel and gasoline and will solve some CO emission problems and minimize the total cost for the generated power.

THE PROPOSED SCHEDULING ALGORITHM

In this work two conventional and two renewable sources are used. The constraints used for wind and solar energy are the wind speed and solar irradiation as seen in equation (1) and (2). Another constraints are added based on the availability.

$$7<\text{Wind Speed}<8.6 \quad \text{……..……(1)}$$
$$950<\text{Solar Irradiation}<1200 \quad \text{…(2)}$$

Figure (1) shows flowchart of the scheduling of the hybrid energy system. The priority in the scheduling is given to the wind and solar energy source, where their availability is compared to each other. The energy source that is available for a longer period will get the priority. In case no one of them is available, the priority will take place to the diesel or gasoline generator whichever has the lowest price, and this is described in the flowchart. The main benefits that obtained from this scheduling is to solve some of CO_2 emission problem and minimize the total cost for the generated power. Figures (2) and (3) show the results attained from the proposed scheduling algorithm with and without battery. The hybrid energy sources without battery are relying on the wind energy source by 41% while the solar energy source and gasoline power are 26% and 33% respectively. Adding the battery to the hybrid energy sources results in decreasing the use of gasoline power. As a result of applying the proposed scheduling algorithm for both scenarios the diesel power is no longer exist due to its price.

Table (1) DIFFERENT METHOD TO SOLVE ECONOMIC DISPATCH PROBLEM.

Reference	Year	Study	Method	Constraints	Finding
[7]	2011	Determining Economic Load Dispatch (ELD) problems with smooth and non-smooth fuel cost objective functions.	Genetic Algorithm	Effects of valve-point loading ripples and line losses.	Adjusting the parameters in Genetic algorithm consumes long time where it is done by trial and error, however it gives good results in power system optimization problem.
[8]	2012	Studying Dynamic Economic Dispatch (DED) problem. Load profile has been used instead of fixed demand.	Multi Objective Particle Swarm (MOPSO).	Ramp rate limits, generation limits and transmission losses.	The algorithm was successfully implemented and in comparing with Brent methods, they found that the computational times are much less than and Brent methods.
[9]	2017	Identifying cost and emission to power system consists of six generators.	VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) Method.	The energy generated must meet the demand side.	The obtained results from VIKOR method is acceptable where it shows good performance in solving these problems
[10]	2018	Determining ELD problems with smooth and non-smooth fuel cost objective functions.	Cuckoo Search Method	Transmission and operational constraints	in comparing the method to the Bat method, it is found that the method displays better performance than Bat method.

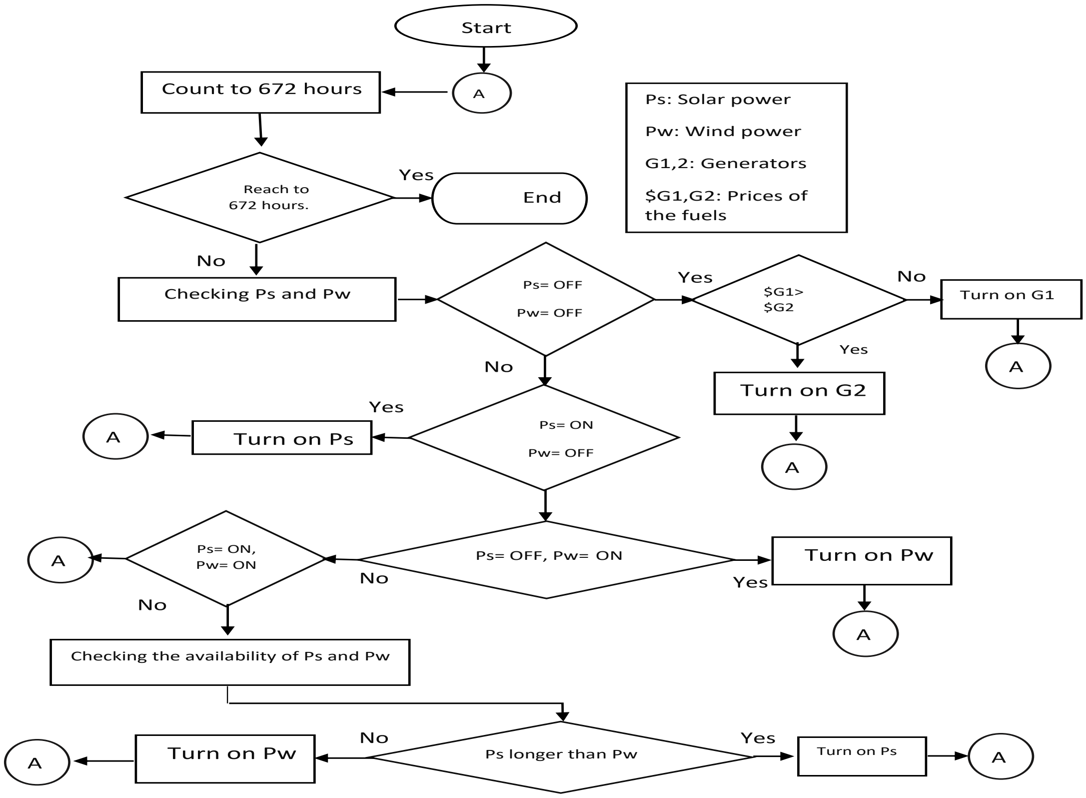

Figure (1) The proposed flowchart of the scheduling of hybrid energy system.

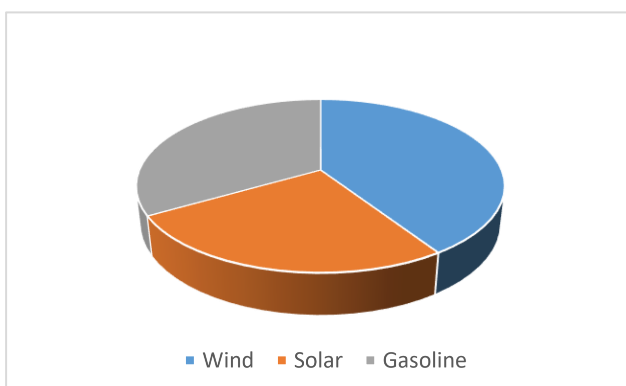

Figure (2) Scheduling results without using battery.

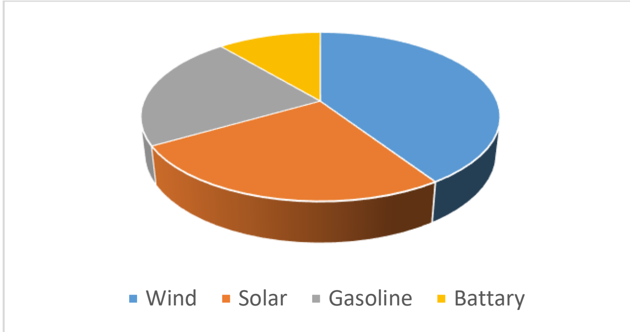

Figure (3) Scheduling results using battery.

CARBON DIOXIDE EMISSIONS

A standard 5-kilowatt generator will typically consume about 0.75 gallons per hour. U.S. Energy Information Administration estimates stated that one gallon produces 19.60 pounds. Then 0.75 gallon will produce 14.7 pounds. Based on the results that we got from table (2) we can say that the gasoline generator will produce 1852.2 pounds of CO2 in 126 hours (4.5 months). Also, from table (3) we can say that the gasoline generator will produce 617.4 pounds of CO2 in 42 hours.

Table 2: Scenario A (Scheduling results without using battery)

Energy	Wind	Solar	Gasoline
Hours	154	98	126
Percentage	41	26	33

Table 3: Scenario B (Scheduling results without using battery)

Energy	Wind	Solar	Gasoline
Hours	154	98	84
Percentage	41	26	22

C0NCLUSION

A proposed flowchart as well is created for the optimal operation of different sources with and without battery bank. A scenario of hybrid system of renewables and conventional energy is created and used for optimal size based on some constraints. Two different scenarios are proposed for the hybrid system based on using battery or not; Scenario A is without battery and scenario B is with battery. Scenario A is described as following 26% solar, 41% wind and 33% gasoline. For scenario A the CO2 emission is found to be 1852.2 pounds in 126 hours. For scenario B; a battery is added to the system and the dependency of the system on gasoline is reduced by one third. The CO2 emission is reduced to 617.4 pounds. The proposed technique is used for forecasting and based on the availability of the renewables the sizing is changing regularly to reduce the fossil fuel emissions and improve the overall system performance.

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