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Development of Optimal Electricity Management Systems to Minimize Resources and Losses using Particle Swarm Optimization Techniques: A Case Study for UDUS

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ABSTRACT

Hybrid energy systems (HESs), have played an important role as clean and efficient source of electricity generation. HESs are often formulated as an optimization problem which is solved mostly using metaheuristics techniques. The conventional objective function is based on levelized cost of energy (LCOE), the lowest loss of power supply probability (LPSP), and the maximum renewable factor (REF) as indices. This paper proposed an enhanced objective function based on additional index known as Lost Load Dump Load Index (LLDLI), which helps in finding optimal solution to HES deployment. Usmanu Danfodiyo University Sokoto (UDUS), Nigeria is used as case study, Particle swamp optimization (PSO)is used to solve the optimization problem in MATLAB/Simulink for its early convergence. With the proposed method, an optimal solution for the allocation of HES resources is achieved with minimum LCOE, LPSP, and LLDL indices that are equal to 1.21$/kWh and 0.04%, and 0.05%respectively against conventional PSO of The minimum parameters come out to be 1.3$/kWh for LCOE, 0.06% for LPSP, 0.09I.

1. INTRODUCTION

Electricity is one of the most essential components of modern life, underpinning economic growth, industrialization, and urban development. However, the electricity sector faces significant challenges in meeting growing demand, reducing costs, and minimizing environmental impacts. In response to these challenges, the global shift toward renewable energy (RE) has intensified. Reports indicate that several countries now produce over 20% of their electricity from renewable sources [1–4].

RE particularly solar and wind, have become a viable option for electrifying remote and off-grid areas due their environmental friendly nature [5, 6]. Thus, in light of global climate concerns, the United Nations has initiated campaigns encouraging nations to adopt clean energy strategies to reduce greenhouse gas emissions [7]. Despite their advantages, renewable sources like solar and wind are inherently intermittent and weather-dependent, resulting in operational instability. This necessitates the integration of RE sources with conventional energy to form hybrid energy systems (HES), which can enhance reliability [8].

An HES combines either multiple renewable sources or a mix of renewable and traditional sources like diesel generators or gas turbines [9]. In this study, a hybrid system comprising photovoltaic (PV), wind turbine, battery storage, and a diesel generator is proposed. Previous studies have demonstrated that integrating REs with diesel generators reduces fuel consumption, Net Present Cost (NPC), Cost of Electricity (COE), and CO_2 emissions while improving reliability especially in developing regions [10–11].

Several optimization techniques have been applied in designing such hybrid systems, including Particle Swarm Optimization (PSO), Genetic Algorithms (GA), and software tools like HOMER. For instance, [12–14] utilized PSO for optimal sizing of wind/PV/battery systems, while [16] extended PSO to include tidal energy. HOMER-based studies [17–19] examined both off-grid and grid-connected scenarios. Additionally, hybrid algorithms such as Harmony Search (HS), Jaya, Ant Colony Optimization (ACO), and Flower Pollination Algorithm (FPA) have been employed for enhanced performance [20–30]. Despite the extensive research, many studies primarily focus on cost optimization without adequately addressing system performance issues such as high dump loads and frequent power shortages (loss of load). Moreover, limited attention has been paid to developing a composite index that simultaneously accounts for energy wastage and supply reliability.

To address these gaps, this paper proposes an optimal sizing approach for a hybrid energy system (PV/Wind/Battery/Diesel Generator) using a **modified Particle Swarm Optimization (MOPSO)** algorithm. A new index, referred to as the **Lost Load Dump Load Index (LLDLI)**, is integrated into the objective function of the conventional PSO for improved performance and early convergence. This enhancement enables simultaneous minimization of dump load and loss.

The main contributions of this study are:

a) Development of a MOPSO-based optimization strategy that incorporates the novel LLDLI metric.
b) Improvement in power supply reliability and system efficiency without significantly increasing cost.
c) Comparative analysis with existing models to demonstrate the superiority of the proposed method in handling intermittency and load mismatches.

This research offers a practical optimization framework for deploying reliable and cost-effective hybrid renewable energy systems, particularly in rural and remote regions of developing countries. In other words, from the previous reviewed most of the researchers, focuses on reducing cost of the system without considering the effect of high dump load and high loss of power supply probability. Thus, an optimal sizing of hybrid energy system (HES) of pv/wind/battery coupled with DG is proposed in this work. However, an additional index referred to lost load dump load index (LLDLI) is integrated into the objective functions of conventional particle swarm optimization algorithm in order to minimized the dump load as well as the lost load. As a result of this, a conventional PSO was employed as an algorithm with the additional index and therefore termed it as modified PSO (MOPSO).

2. SYSTEM MODEL DESCRIPTION

The proposed system comprises of a solar PV, wind turbine, and diesel generating system which are being supported by a Battery storage. The power generated by the renewable sources is transferred via DC/DC converter to a DC bus. The DC power will then be converted to AC via DC/AC converter. The diesel generating system is connected directly to the AC bus together with the AC load as well as the dump load. The excess power generated by the renewable energy components is used to charge the battery. In an event where the generated power cannot supply the load, the stored energy from the battery will be used to support the load. However, if the generated power and the stored power cannot meet the load requirements, the diesel generating systems come up to support the load as well charge the battery systems. The block diagram of the proposed HES is depicted in Figure 1.

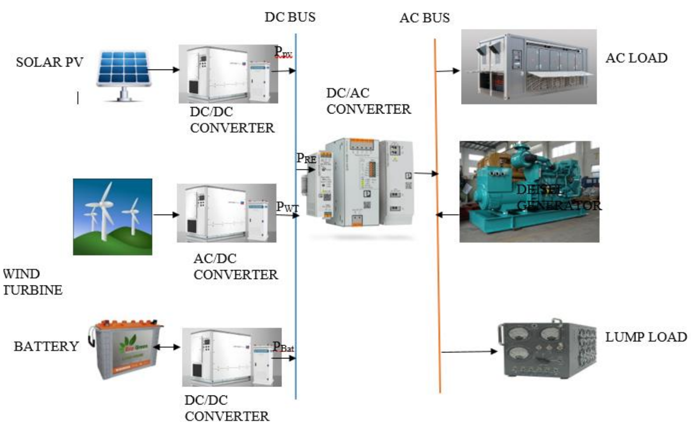

Figure 1: Block diagram of proposed HES.

2.1 A PV system modeling

The Power produced out of the PV energy system is estimated according to the solar radiation and the cell temperature is given by equation 1 [23].

$$P_{pv} = \frac{G \times P_r \times \left[1 + K\left(\left(T_{amb}\left[\left(TNOCT - 20\right)/800\right]G\right) - T_{ref}\right)\right]}{G_{ref}} \quad (1)$$

Where P_{PV} and P_r are the output power of the PV and the rated power in watts (W) at the standard test condition (STC), respectively. K is the temperature coefficient, defined as (-3.7×10^{-3} (1/°C)). T_{ref} denotes the cell temperature (°C) at STC, T_{amb} denotes the ambient temperature (T_{amb} =25 °C); G is solar radiation (W/m^2); G_{ref} is solar radiation at STC (G_{ref} =1000W/m^2); TNOCT is the nominal operating cell temperature. The DC/AC converter or the inverter convert the energy produced from the PV generator sources form DC to AC. The efficiency is expressed as equation 2 [1],with respective parameters given as equations 3 through 5.

$$\eta_{inv} = \frac{P}{P + P_0 + kP^2} \tag{2}$$

$$P = \frac{P_{out}}{P_{Nom}} \tag{3}$$

$$P_0 = \frac{\frac{10}{\eta_{10}} - \frac{1}{\eta_{100}} - 9}{99} \tag{4}$$

$$k = \frac{1}{\eta_{100}} - \eta_0 - 1 \tag{5}$$

Where η_{10} *and* η_{100} are the inverter efficiency value at 10% and 100% of its nominal power.

2.2 Wind Energy System modeling

Due to the uncertainty nature of the wind, in order to determine the wind generator output power, the measured wind speed at reference height is first converted to corresponding wind turbine (WT) hub height. The power law equation is computed as equation 6 equation [23].

$$\frac{V_1}{V_2} = \left(\frac{h}{h_{ref}}\right)^{\alpha} \tag{6}$$

Where h (m) is the WT hub height, and h_{ref} (m) is WT reference height. V_1 (m/s) is the wind speed at WT hub height and V_2 (m/s) is the speed at the reference height. α is the power-law exponential (also known as Hellmann exponent, wind gradient, or power law exponent). Similarly, the wind turbine output power can be expressed as equation 7:

$$P_{WT} = \begin{cases} 0 & V \prec V_{cut-in} \\ V^3\left(\frac{P_r}{V_r^3 - V_{cut-in}^3}\right) - P_r\left(\frac{V_{cut-in}^3}{V_r^3 - V_{cut-in}^3}\right) & V_{cut-in} \le V \prec V_{rated} \\ P_r & V_{rated} \le V \le V_{cut-out} \\ 0 & V \succ V_{cut-out} \end{cases} \tag{7}$$

Where P_r (kW) is the rated power of the WT, $V_{cut-out}$ (m/s) is the cut-out speed of the WT, V_r (m/s) is the nominal speed of the WT , V_{cut-in} (m/s) is the cut-in speed of the WT and V (m/s) is the wind speed.

2.3 Battery Energy Storage System modeling

The essence of battery energy storage in this system is to serve as a back-up in the absence of renewable energy sources so as to meet the load demand before the DG comes up to avoid loss of power supply. The battery capacity is designed based on desired day of autonomy and energy demand based on the equation 8 [23].

$$C_B = \frac{P_{load} \times AD}{\eta_{Bat} \times DOD \times \eta_{inv}} \tag{8}$$

Where DOD is the depth of discharge usually (80%), η_{inv} is the inverter efficiency usually (95%), η_{Bat} is the battery efficiency usually (85%) and AD is the number of autonomy day. Similarly, the state of charge of the battery at a time (t) is given by SOC (t) with maximum and minimum state respectively. When any of the RE sources produces excess or deficit energy, this excess or deficit energy denotes the power that is either absorbed or delivered by the battery. This can be expressed as equation 9.

$$P_{Bat}(t) = P_{pv}(t) + P_{WT}(t) - \frac{P_{load}(t)}{\eta_{inv}} \tag{9}$$

Where $P_{Bat}(t) \prec 0$ indicates that the power generation has deficit in energy demand and if $P_{Bat}(t) \succ 0$ indicates a surplus in power generation at a given time instance. Moreover, the charging of the BES occurs at a time when $SOC(t) \prec SOC_{\max}$ and when $\left(P_{PV}(t) + P_{WT}(t) > P_{load}(t)\right)$. Thus; $SOC(t)$ can be as expressed as equation 10.

$$SOC(t) = SOC(t-1)(1-\gamma) + \left(P_{Bat}(t) \times \eta_{Bat}\right) \quad (10)$$

And when there is shortage in power generation and $SOC(t) \succ SOC_{\max}$ then the battery energy storage will discharge the energy stored to meet the load demand as given in equation 11.

$$SOC(t) = SOC(t-1)(1-\gamma) + \left(-P_{Bat}(t) \times \eta_{Bat}\right) \quad (11)$$

Where γ is the self-discharging rate of the battery storage system,

2.4 Diesel Generator modeling

The diesel generator serves as an alternative source when the RE and battery cannot meet the load during peak periods. Another factor of consideration in DG modelling is the fuel consumption which can be expressed as equation 12 [23].

$$F(t) = aP_{DG}(t) + bP_r \quad (12)$$

Where P_{DG} is the generated power (kW), $F(t)$ is the fuel consumption rate in (L/hour), P_r is the rated power (kW) of the DG. While *a* and *b* are constant parameters in (L/kW), which represent the coefficients of fuel consumption, and can be approximated to 0.246 and 0.08415, respectively. Also, the efficiency of the DG can be calculated as equation 13.

$$\eta_{overall} = \eta_{break-thermal} \times \eta_{generator} \quad (13)$$

Where $\eta_{overall}$ is the overall efficiency of the DG and $\eta_{break-thermal}$ is the brake thermal efficiency of the DG.

2.5 Particle Swamp Optimization (PSO) Technique

The main aim of any optimization problem for HES is to find the optimal solution for allocation of resources that will find the suitable allocation of HES resources for efficient and reliable power generation, one of the metaheuristics techniques used is particle swamp optimization (PSO) The particles swam optimization (PSO) technique was developed by Eberhart and Kennedy in 1995 for solving non-linear, multidimensional objective function optimization problems [19]. The searching strategy of PSO algorithm is inspired by the social behaviors of birds flocking or fish schooling, where each particle of the swarm acts as a potential solution of certain optimization problem. PSO algorithm is employed to intelligently select optimal parameters from N particles.

The initialization matrix contains N particles dispersed in a search space of D-dimension. At the k^{th} iteration in the searching process, the i^{th} particle stores its historical best position P_{best} as represented by $\left(p_{best}(k) = p_{i1}(k), p_{i2}(k)......p_{iD}(k)\right)$ and its global best particle P_{gbest} as denoted by $\left(p_{gbest}(k) = p_{gbest1}(k), p_{gbest2}(k)......p_{gbestD}(k)\right)$. The process of displacement of each particle is achieved by the following rules.

- The particle tends to take the direction of its current velocity
- The particle tends to move toward its best position
- The particle tends to move to the best position reached by its neighbors

Similarly, the position of the particle i will be updated to reach the global optimum based on the corresponding velocity vector. Moreover, the velocity and the position vectors of the particle i at the iteration k will be determined by the equations 14 and 15 respectively.

$$V_i(k+1) = wV_i(k) + c_1 r_1\left(p_{best}(k) - x_i(k)\right) + c_2 r_2\left(p_{gbest}(k) - x_i(k)\right) \quad (14)$$

$$x_i(k+1) = x_i(k) + V_i(k+1) \quad (15)$$

Where k is the number of the current iteration w is the inertia weight c_1 and c_2 are the acceleration coefficients respectively, cognitive and social parameters r_1 and r_2 are two uniformly distributed random numbers between (0, 1) [23]. Figure 2 depicts the flowchart of PSO.

3 METHODOLOGY

3.1 Conventional method of objective function formulation

The conventional objective function is formulated using the following indices: levelized cost of energy (LCOE), loss of power supply probability (LPSP) and renewable factor (RF). The objective function is formulated as equation 16.

$$\min\left(OF = w_{LCOE}LCOE + w_{LPSP}LPSP + w_{RF}RF\right) \quad (16)$$

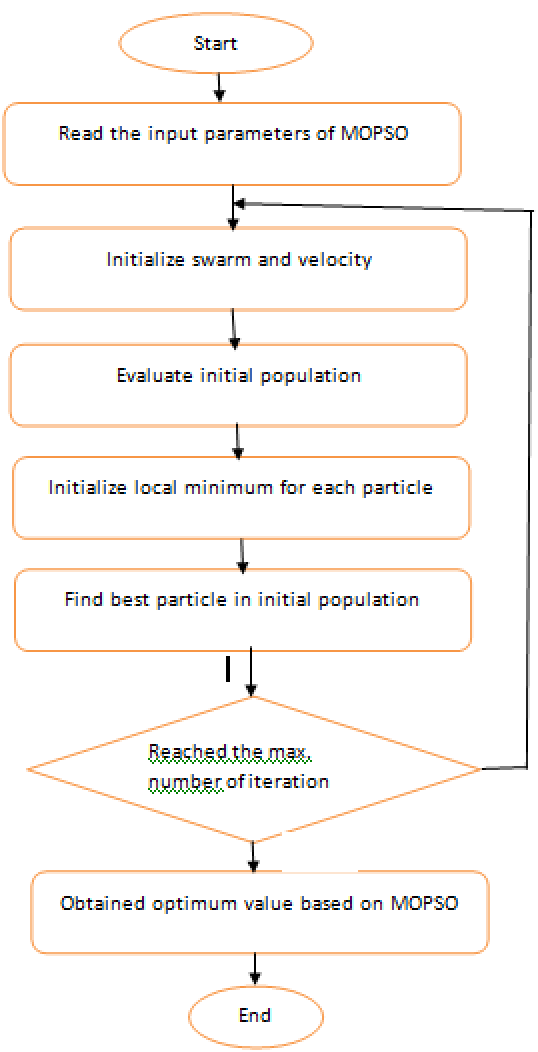

Figure 2: Flowchart of solving optimization problem with PSO.

3.1.1. Levelized Cost of Energy (LCOE)

This includes the initial cost and operation and maintenance cost of the system. It is the price of each unit of energy produced ($/kw). It can be computed as the cost (Mohammed et al, 2022). To convert the initial cost into an annual capital cost, the capital recovery factor CRF is given as [31] With I is the interest rate and n is the life span of the system components. Equations 17 through 19 represent the LCOE index.

$$LCOE = \frac{\left(C_{PV} + C_{WT} + C_{DG} + C_{BES}\right)CRF}{\sum_{t=1}^{8760} P_t^{Load}} \quad (17)$$

$$LCOE = \frac{(NPC)CRF}{\sum_{t=1}^{8760} P_t^{Load}} \quad (18)$$

$$CRF = \frac{i(1+i)^n}{(1+i)^n - 1} \quad (19)$$

Cost of Solar PV $\left(C_{PV}\right)$ is given as equation 20, with C_{PV}^{Cap} as the capital cost of the PV panel and $C_{PV}^{O\&M}$ is the operation and maintenance cost of the PV panel

$$C_{PV} = \left(C_{PV}^{Cap} + C_{PV}^{O\&M}\right)P_{pv} \quad (20)$$

Cost of inverter $\left(C_{INV}\right)$ system is given as equation 21, with C_{INV}^{Cap} as the capital cost of the inverter system and $C_{INV}^{O\&M}$ is the operation and maintenance cost of the inverter system

$$C_{INV} = C_{INV}^{Cap} + C_{INV}^{O\&M} \quad (21)$$

Cost of wind turbine $\left(C_{WT}\right)$ is given as equation 22, with C_{WT}^{Cap} is the capital cost of the wind turbine and

$C_{WT}^{O\&M}$ is the operation and maintenance cost of the wind turbine.

$$C_{WT} = C_{WT}^{Cap} + C_{WT}^{O\&M} \quad (22)$$

Cost of battery energy storage system $\left(C_{BES}\right)$ is given as equation 23, with C_{BES}^{Cap} is the capital cost of the battery energy storage system

$C_{BES}^{O\&M}$ is the operation and maintenance cost of the battery energy storage system.

$$C_{BES} = C_{BES}^{Cap} + C_{BES}^{O\&M} \quad (23)$$

Cost of diesel generator $\left(C_{DG}\right)$ is given as equation 24, with C_{DG}^{Cap} is the capital cost of the diesel generator and $C_{DG}^{O\&M}$ is the operation and maintenance cost of the diesel generator

$$C_{DG} = C_{DG}^{Cap} + C_{DG}^{O\&M} + C_{DG}^{Fuel} \quad (24)$$

3.1.2. Loss of power supply probability (LPSP)

This is the probability of the entire system to meet the load demand. The LPSP is a reliability index, which indicates the probability of the power supply failure to meet the energy demand. The LPSP value must be less than 5% based on the literature. It can be expressed equation 25 [23].

$$LPSP = \frac{\sum P_L(t) - \left(P_{PV}(t) - P_{WT}(t) + P_{DG}(t) + P_{Bat\min}\right)}{\sum P_L(t)} \quad (25)$$

Where $P_{WT}(t)$ is the amount of power generated by the wind turbine at a time t, $P_{PV}(t)$ is the amount of power generated by the PV system at a time t, $P_{DG}(t)$ is the amount of power generated by the diesel generator at a time t, $P_{load}(t)$ is the amount of power consumed at a time t and $P_{Bat\min}(t)$ is the minimum allowable storage capacity of the battery storage system.

3.1.3 Renewable factor (RF)

The renewable factor (RF) is the ratio between the conventional diesel generator power to the renewable energy sources. The best system is aimed to minimize the utilization of diesel generator, and hence minimizes the operation cost and CO_2 emission as:

$$RF(\%) = \left(1 - \frac{\sum P_{DG}(t)}{\sum P_{PV}(t) + P_{WT}(t)}\right) \times 100 \quad (26)$$

Where $P_{WT}(t)$ is the of power generated by the wind turbine at a time t, $P_{PV}(t)$ is the power generated by the PV system at a time t, $P_{DG}(t)$ is the amount of power generated by the diesel generator at a time t.

4.2 Proposed method of objective function formulation

The LLDLI is proposed here to be the ratio between the lost load and the dump load. This will help to balance the system to avoid selection of many microgrid components that will generate unwanted excess power by the system. The LLDLI will also monitor and maintain a minimum LPSP, equation 27 represents the proposed index. Substituting equation 27 into equation 16, equation 28 is the proposed objective function, which is used to enhanced optimal allocation of HES resources, therefore making the system more cost effective with reduced loss, while maintaining the quality and reliability of electric power generated and an additional feature called the Loss Load Dump Load Index (LLDLI). The LLDLI is the ratio between the lost load and the dump load. Where P_{LOAD} is the total load demand and P_{EXT} is the excess power generated.

$$LLDLI = \left| \frac{\left(\sum \left| P_{EXT}\left(P_{EXT} \le 0\right)\right|\right)}{\sum P_{LOAD} - \sum\left(P_{EXT} \ge 0\right)} \right| \quad (27)$$

$$\min\left(OF=\left(w_{LCOE}LCOE+w_{LPSP}LPSP+w_{RF}RF\right)+\left(w_{LLDLI}LLDLI\right)\right) \tag{28}$$

The system constraints are the high percentage of the renewable factor, minimum or zero LPSP and the renewable energy resources design constraints including the BES system, which will ensure optimal energy generation. Thus, the main objective function is minimizing the system operational cost. Equations 29 through 31 are the constraints for the proposed objective function of the HES. The flowchart pf the proposed hybrid energy management system is depicted in Figure 3, while the optimization parameters are given in Table3.

$$0 \le RF \le 100 \tag{29}$$

$$\left|LPSP\right| \le 0 \tag{30}$$

$$\begin{cases} 0 \le N_{PV} \le 7451 \\ 0 \le N_{WT} \le 500 \\ 0 \le N_{BES} \le 1563 \end{cases} \tag{31}$$

Table 1: PSO simulation parameter

Parameter	Values
Population size	50
Maximum number of iterations	100
Cognitive parameter C_1	1
Social parameter C_2	3

4 RESULTS AND DISCUSSION

5.1 Simulation Results

The simulation of the HES optimization process was conducted using MATLAB R2018a software. The software was installed on a TOSHIBA PC with properties of 8GB RAM, 1.8GHz intel core i5 processor. Simulation studies were conducted for both the conventional and proposed objective function, while PSO algorithm is employed to solve the optimization problem for both cases. The optimization is run for each combination using 50 numbers of swarms as the population size and 100 iterations. The conventional and proposed objective functions for the, similarly, the system resources capacities which include PV panels, WT, battery storage system and diesel generator are obtained.

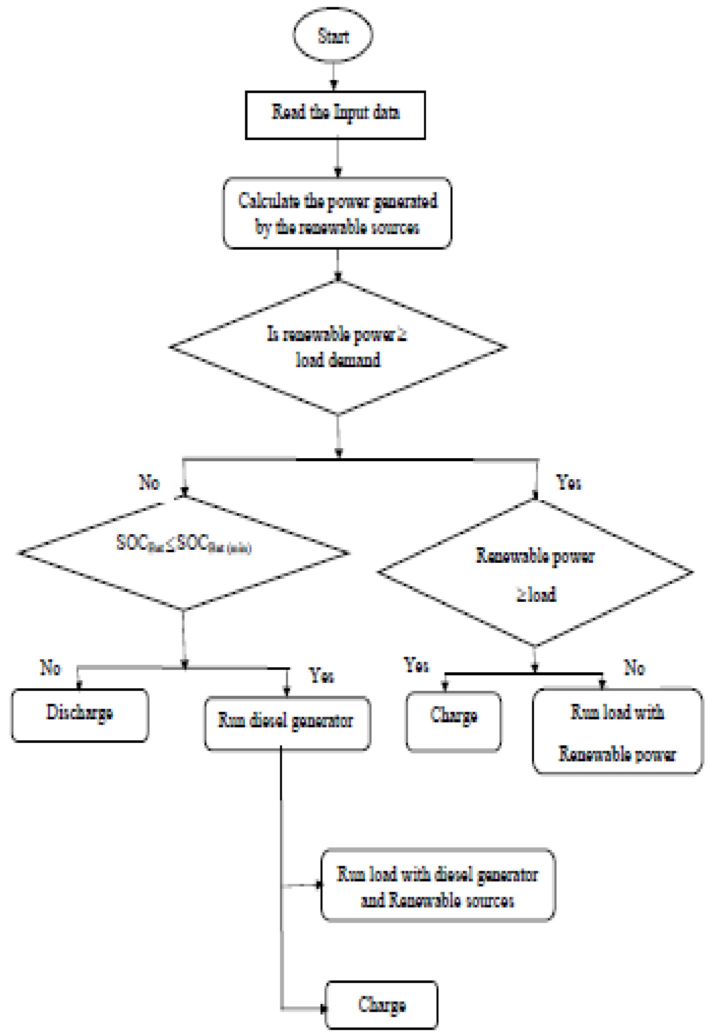

Figure 3: Flowchart of the proposed management of HES

The conventional and proposed objective functions for the, similarly, the system resources capacities which include PV panels, WT, battery storage system and diesel generator are obtained. The research work is compared with the conventional objective function presented by the work in [17] and could be deployed in power electronics devies used in electricity energy converters [33-53] such as STATCOM, MPPTs and inverters. With the proposed objective function, all other indices of the conventional objective functions were minimized; also the convergence rate of the PSO is improved with the proposed conventional function. Table 2 represents the values of indices of both methods, while Figure 4 depicts the convergence characteristics of the PSO using both methods.

Table 2: Comparison indices for the conventional and proposed method

Objective Function	LCOE	LPSP	REF	LLDLI
Conventional	0.246972	0.295228	6.308086	-
Proposed	0.160518	0.243792	37.98826	0.339373

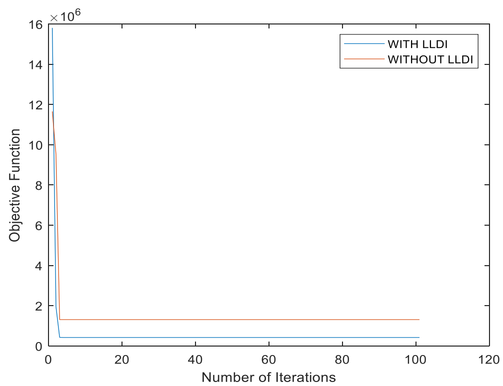

Figure 4: Convergence characteristics of the PSO with both methods.

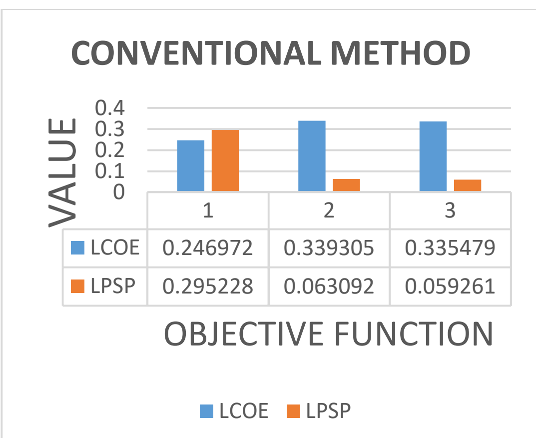

Figure 5: Results of LCOE and LPSP with conventional method.

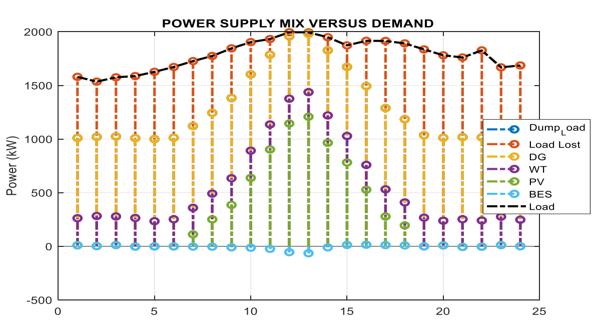

Figure 7: Output Power supply of the HRES.

Figure 5 and Figure 6 depicts the comparison of LCOE and LPSP for conventional and proposed method respectively. The proposed lost load dump load index (LLDLI) improves reliability and reduced cost in an optimal sizing of hybrid renewable energy system, while the convergence rate of the PSO improved with the proposed method. Result obtained for the best configuration shows a total of 7451units of PVs, 500 unit of WT, 1563 units of BES and 8 units of DG will be installed to supply the load demand of approximately 2500kW. The minimum parameters come out to be 1.207377$/kWh for LCOE, 0.038949% for LPSP, 0.049736% LLDLI and 102% for REF. Figures 7 and 8 depicts the power and energy contributed by HES individual components to satisfy the load demand installed to supply the load demand of approximately 2500kW. The minimum parameters come out to be 1.207377$/kWh for LCOE, 0.038949% for LPSP, 0.049736% LLDLI and 102% for REF. Figures 7 and 8 depicts the power and energy contributed by HES individual components to satisfy the load demand.

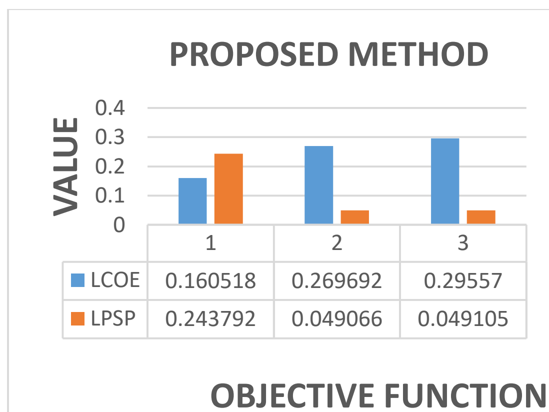

Figure 6: Results of LCOE and LPSP with proposed method.

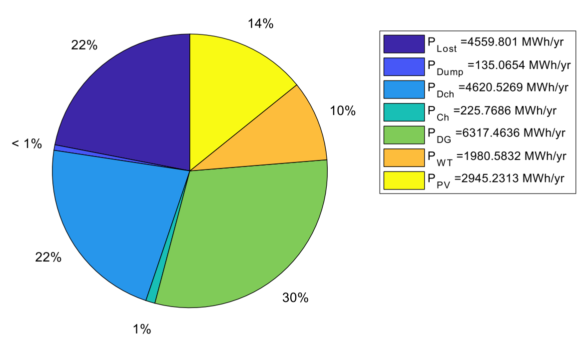

Figure 8: Annual Energy Contribution of the HES.

From Figure 7, the average power generated by each component is, 2,459kW PV, 2,500kW WT, 2,800kW DG and 2,501kWh battery. If the total power generated satisfied the load, and the excess power will be used to charge the battery storage system. The energy supplied annually is depicted in the pie chart given in figure 8 The amount of energy supplied by each source indicated that, DG will supply most of the load with 6317.4636MWh/yr amounting to 30% of the total energy supplied. Other parameters such as the PV, WT, charge and discharge energy, dump and lost energy were summarized. P_{PV} 2945.2313MWh/yr, amounting to 14% of the total energy, P_{WT} is 1980.5832MWh/yr, amounting to 10% of the total energy, P_{Loss} is 4559.801MWh/yr amounting to 22% of the total energy, P_{Dump} is 135.0654MWh/yr amounting to less than 1% of the total energy, PDCH is 225.7686MWh/yr amounting 1% of the total energy. From the results, the effect of and important of LLDLI was seen clearly as the amount of dump load is less than 1% of the entire generation. Similarly, various graphs were plotted for the effect of variation of LPSP and other objective function parameters such as LCOE, REF, cost, and the entire HES components. Figures 9 through 14 depict the results. The effect of LPSP in optimal sizing of HRES can be obviously observed from the entire simulation result. The entire system component, the cost of the components and the reliability of the system were observed to decrease or increases with increase or decrease of LPSP. Hence the best optimal sizing of hybrid energy system can be achieved with the best choice and selection of a better constraint of LPSP.

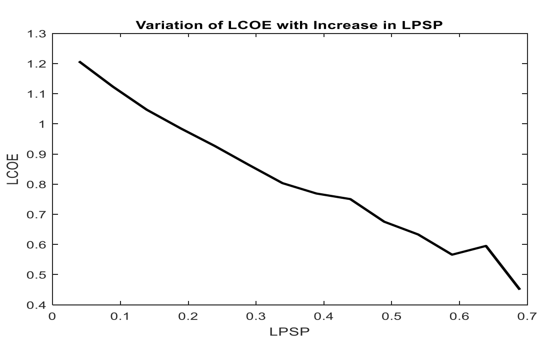

Figure 9: Variation of LCOE with increase in LPSP.

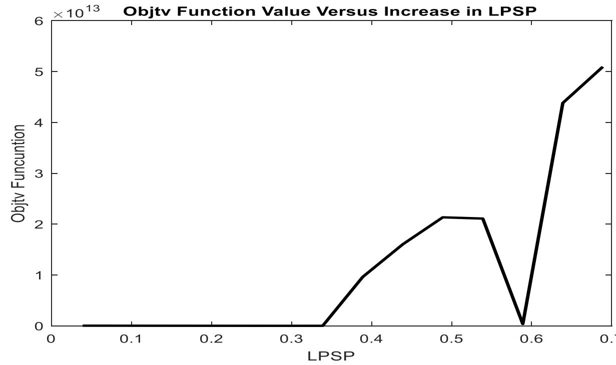

Figure 10: Variation of objective function with increase in LPSP.

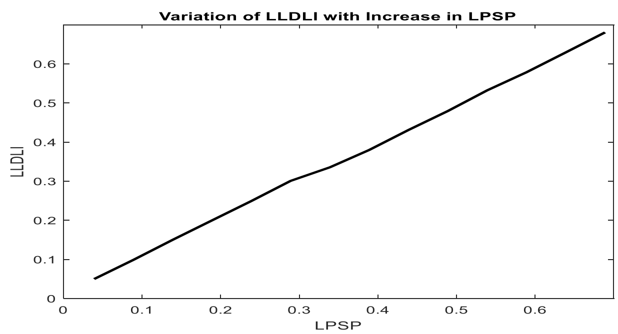

Figure 11: Variation of LLDLI with increase in LPSP.

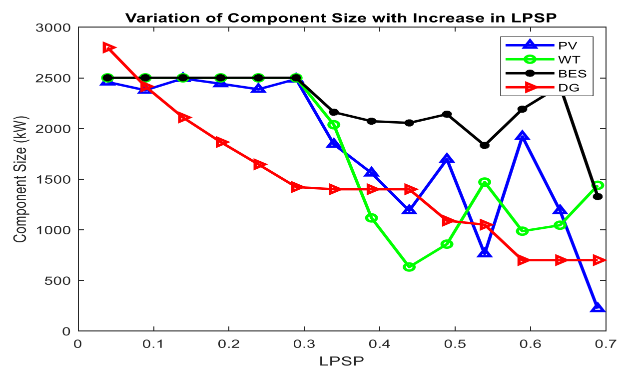

Figure 12: Variation of component sizes with increase in LPSP.

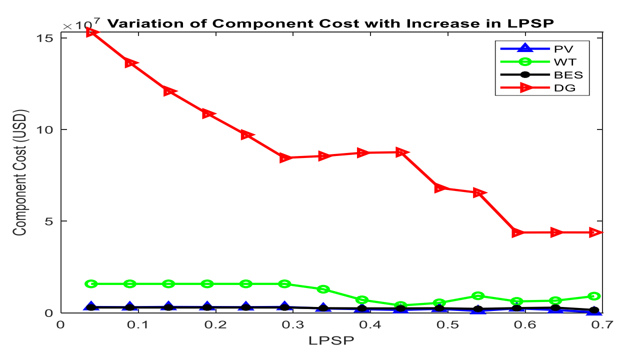

Figure 13: Variation of component cost with increase in LPSP.

6. CONCLUSION AND FUTURE WORK.

In this research work, a hybrid energy system (HES) optimization problem is developed and solved with Particle Swarm Optimization (PSO) optimal sizing of the system of Usmanu Danfodiyo University Sokoto in Sokoto Nigeria. The developed HES system model comprises of PV panels, WTs, DGs, and battery storage systems. The levelized cost of energy (LCOE), the minimum loss of power supply probability (LPSP), and the maximum renewable factor (REF) and proposed minimum lost load dump load index (LLDLI) are defined as objective functions. The results of the optimization in this location with the proposed method, an optimal solution for the allocation of HES resources is achieved with minimum LCOE, LPSP, and LLDL indices that are equal to 1.21$/kWh and 0.04%, and 0.05%respectively against conventional PSO of The minimum parameters come out to be 1.3$/kWh for LCOE, 0.06% for LPSP, 0.09I.Therefore, using renewable energy to generate electricity can be considered as a good alternative to enhancing clean energy access especially in remote areas. Results obtained demonstrate a high efficiency of the successful application of the PSO for the proposed system compared to several research contributions in the literature. The utilization of the proposed method can help to overcome some of the technical problems that limits the performance of optimal sizing of a hybrid system. Future research should include optimization of energy management considering electric vehicle, hosting capacity of the university distribution system to 100% renewable integration and electric market design including peer to peer (P2P) trading.

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