Techno-Economic Feasibility Analysis of Hybrid Renewable Energy System By Using Particle Optimization Technique for the Rural Border Areas in Iraq : Case Study

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Abstract: A truly need and biggest challenge that the border rural areas are suffering is difficult chance to connect to electricity grid due to nature of area and distance among population centers. A case study in this paper, Al-Teeb Area is located in the southeastern of Iraqi-Iranian border. To overcome on this dilemma, a best substitute is Hybrid Energy System (HES). The Techno-Economic Feasibility analysis of grid-tied by photovoltaic(PV) -battery(BT) - wind turbine(WT) - diesel generator (DG) in that region are focus in this research.. This study made use of the MATLAB-based three different types of Particle Swarm Optimization algorithms(PSO),namely,(Modified PSO, Canonical-PSO and Hierarchical PSO with Time-varying Acceleration Coefficients (HPSO-TVAC) When designing a HES, it is important to strike a balance between the three goals of Cost Of Energy (COE), Reliability (REL), and maximizing the value of Renewable Energy Penetration (REP). Based on the results from the first type of PSO algorithm were found to be the most suitable for implementing this system were as follows, the ideal values for Number of Photovoltaic (NPV) (1235), Number of Wind Turbines (NWT) (58), Number of Diesel Generators (NDG) (12), Number of Batteries (NBT) (3112), Number of Converters (NCon)(46), COE (0.117 US$/KWh), loss power supply probability (LPSP) (0.2065%), REL (79.35%), REP (18%) and TNPC (9.36 MUS$). In addition, the results show that the algorithm efficiently and effectively found ideal solutions to lower total costs. Finally, it was determined that HES was a suitable way to fulfill the electrical demands of rural, outlying areas in Iraq and other developing countries with comparable temperatures.

Keywords: Particle Swarm Optimization (PSO), MATLAB, Hybrid System, Economical Cost, Optimization.

1. Introduction

Concerns over the use of non-renewable energy sources have lately grown in response to many worldwide issues brought on by the higher cost of electricity as a consequence of growing electrical power usage. The rise of severe economic and political ramifications on a global scale has been precipitated by environmental degradation, which in turn is caused by unregulated electrical power production, climatic variance, and global warming[1] . Consequently, countries have pushed for renewable energy sources. By making clean, affordable, and environmentally friendly energy more widely available, renewable energy generation may help nations achieve their sustainable energy production targets [2]. Renewable energy offers many advantages, but it isn't without its drawbacks, such as inefficiency and unreliability in generation caused by weather fluctuations, instability, and other irregularities [3]. In [4],the study is conducted in the city of Zerbattiya, Iraq by using MATLAB-PSO, This study addresses rural energy availability in developing countries, focusing on Zerbattiya, Iraq. The paper suggests an HRES with solar panels, wind turbines,

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diesel generators, and batteries. A techno-economically viable solution is sought by optimising component sizes using the MATLAB Particle Swarm Optimisation (PSO) method. Reduce energy cost (COE) while increasing dependability (REL) and renewable energy penetration. Algorithms recommend 30 solar panels, 30 wind turbines, 3 diesel generators, and 281 battery units. COE = 0.142 US$/kWh, LPSP = 0.0534%, REL = 99.9466%, and REP = 56.35%. The research found that HRES can cover the power demands of distant rural Iraq and other developing countries.

Ref.[5] focuses on rural agricultural communities in the Southern Philippines by using Multi-Objective Particle Swarm Optimization in MATLAB (MATLAB-MOPSO), This project designs and tests an off-grid hybrid renewable energy microgrid (HREM) for Southern Philippines rural farming villages. The research integrates run-of-the-river hydropower, PV, a diesel generator, and a battery energy storage system for optimum size and operation. Multi-objective particle swarm optimization (MOPSO) and a multi-case power management technique minimize competing goals including LPSP, LCOE, and greenhouse gas (GHG) emissions. Different criteria are used to pick four non-dominated solutions from 200 after optimization. The appropriate sizes for the key components are calculated to enable reliable system operation, and the suggested HREM design meets the area's electricity demands.

The study in [6] focuses on a remote area in Comoros by using MATLAB-PSO, This project attempts to build a hybrid energy system for rural electrification in Comoros using renewable and generating sources. The system has solar cells, a wind turbine, and a generator with batteries. In rural locations, solar energy is simple to adopt and maintain, but its cost per Watt for medium and high power is considerable. Engineers investigate hybrid systems (wind, solar, diesel) to optimise storage and save expenses. A wind-photovoltaic-diesel system shows significant profit, decreased capital expenditure, and better cost-effectiveness, according to the research. The main goal is to optimise energy system efficiency, dependability, and storage limits to minimise installation costs, maybe employing supplementary generators. The findings reveal that a wind/diesel generator combination is more feasible and economically advantageous than other scenarios, optimising the hybrid system.

Ref.[7] focuses on rural areas, likely in a country that has islands or remote zones by using Harmony Search, Particle Swarm Optimization and Jave (MATLAB-HS,PSO, Jave), The Wind-Photovoltaic-Biomass-Battery Hybrid Renewable Energy System (HRES) for island energy production is optimised in this study. To find the best cost-effective and efficient arrangement, the research uses Harmony Search (HS), Jaya, and PSO algorithms. The hybrid system's reliability and efficiency are assessed using LPSPmax and EFFmin. Thirteen solar PV systems (70.98 kW), four biomass systems (160 kW), one wind turbine (20 kW), and 15 NI-Fe battery banks (288 kWh) are modelled and optimised to provide the best solution. The cheapest ($581,218) and best-performing setup has a 0.254 $/kWh energy cost.

To meet total energy needs, hybrid renewable energy systems might solve issues with efficiency, dependability, and cost [8]. Hybrid renewable energy systems that combine technologies like solar modules and wind turbines with alternative energy storage systems have been the subject of several research that aim to maximize their size, design, control, and economics [9]. There have been prior applications of a variety of optimization techniques, software, and analytical methodologies to circumvent the limits of such solutions [10]. It is challenging to establish a globally optimal solution due to the contentiousness surrounding the use of hybrid resources. This has prompted the development of a plethora of AI algorithms [11]. Particle swarm optimization is one of these techniques; it is both popular and smart; it can deal with nonlinear problems issues while sidestepping the bare minimal solution [12][13]. Particle swarm optimization was used to determine the best performance in this investigation. Algorithmic particles allowed the program to get optimal outcomes, which fit in with the conventional formula and locate the nearest ideal particle. In addition, the greatest particle in the group might be used to verify for the following iteration as the algorithm reviews all particles. There are multi-objective optimization functions that can make use of particle swarm optimization as well [14]. To meet the electricity demands focused in the Al-Teeb Area metropolis in southeastern Iraq, standalone hybrid renewable energy systems rely on PV/WT/DG/BT. The results showed that Particle Swarm Optimization is a good tool for optimizing hybrid systems, and it helped with issues including energy management, energy cost, and component size.

In addition, these findings were arrived at quickly and accurately, particularly when taking into account the constraints of dependability, the penetration of renewable energy sources, and the plans for future development growth.

2. Details of Selected Region

2.1. Population and location

Fig.1 shows the isolated city of Al-Teeb Area in southern Iraq, not far from the Iranian border. an area of 2070 km2, a height of 70 m, and is located at 32°25′34″ and 47°10′06″.

2.2. Load demand and case study

The national grid supplies some of the electricity to Al-Teeb Area. The power supply accounts for 75% of the overall energy demand in the Al-Teeb Area, which is a major concern. The Iraqi Ministry of Electricity (MOE) reports that power consumption rises by 1% each year, with a system lifespan of 20 years [4]. Therefore, it is assumed that the micro-grid renewable network will only be able to provide 50% of the system's power during its lifetime. To achieve a typical electrical demand amount for the hybrid system, this scenario employed and scaled data obtained hourly in the year 2024. As stated in Table 1 and Table 2, These data were obtained by the Municipality of Maysan Governorate in Iraq, Agricultural Land Department, through a field visit to the Al-Teeb Area has 500 houses, 1 School and 10 Shopping stores. According to Table 2 the energy consumption rates of homes (20,646KWh/day), School (21.042 KWh/day), and Shopping stores (53.84 KWh/day). The metropolitan metropoli Table 1. Load of the homes s of Al-Teeb Area's yearly energy consumption was found to be about 20,720.882KWh/day, according to the load information data with half of the supply coming from the national grid. .

Table 1. Load of the homes

Load	Quantity	Usage Hours	Power (W)	Total load (KW)	Total load (KWh/day)
Lights	8	12	15	0.120	1.440
Ceiling fan	4	24	52	0.208	4.992
Washing machine	1	1	350	0.350	0.350
Refrigerator	1	20	220	0.220	4.400
Ventilating fan	2	6	38	0.076	0.456
TV.	1	15	300	0.300	4.500
Water pump electric	1	2	375	0.375	0.750
Electric water heater	1	4	1000	1.000	4.000
Air Condition	2	12	1095	2.190	52.56
Electric iron	1	1	1000	1.000	1.000
Total load for one household				5.839	41.292
Total load for 500 households				2919.5	20,646

Table 2. Load demand of Al-Teeb Area.

Load	Quantity	KW	KWh/d	Total load (KW)	Total load (KWh/d)
Homes	500	5.839	41.292	2,919.5	20,646
School	1	0.609	16.614	3.757	21.042
Shopping stores	10	0.302	5.384	3.02	53.84
Total daily energy load		6.75	63.29	2926.277	20,720.882
After 20 years					24,865.0584

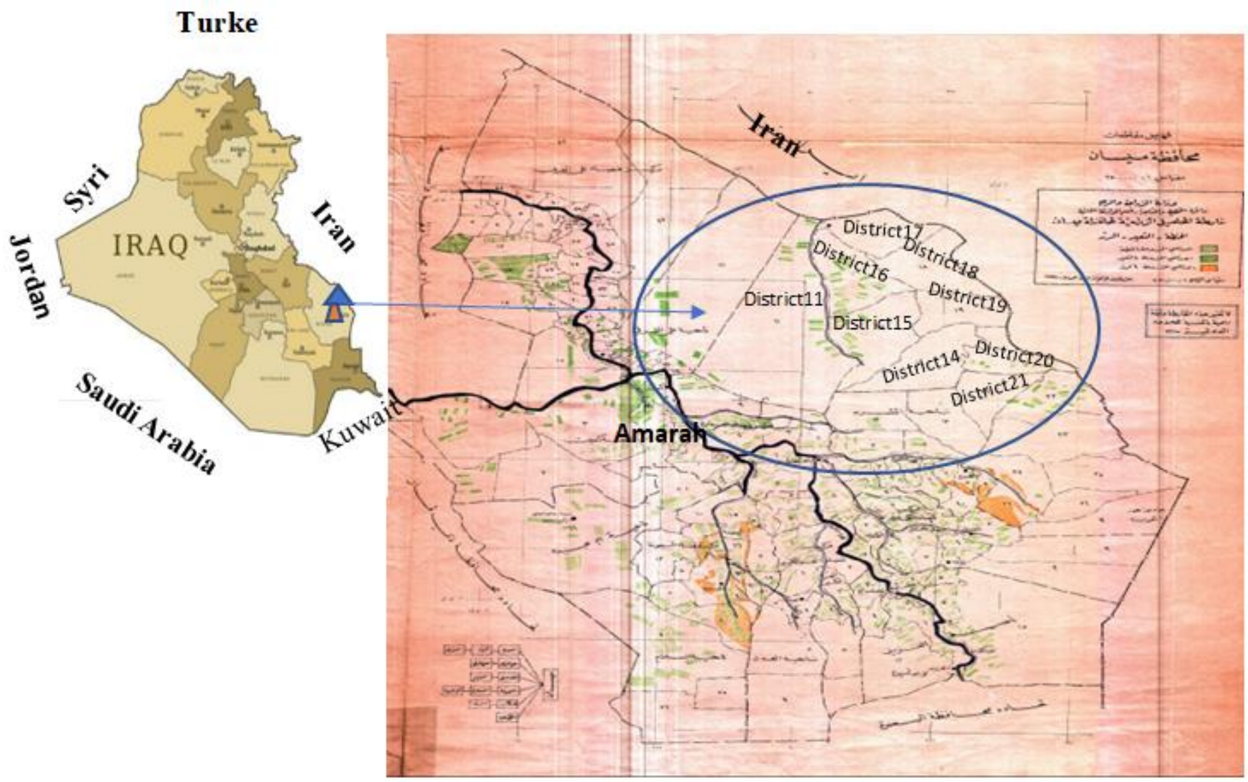

Figure 1. Study area- rural agricultural area composed of nine district unelectrified sites in Al-Teeb Area, Amarah city, Iraq.

2.3. Hybrid system description

In order to ensure that the city of Al-Teeb Area has access to sufficient power, this research expands upon previous work in the field of hybrid renewable energy systems by suggesting a combination of PV, WT, DG, BT and Con. What follows is a discussion of the suggested approach of optimizing and predicting using Particle Swarm Optimization (PSO).

I. Solar Panel

Solar energy is a practical renewable energy source, and Iraq's sunny environment is one of its geographical advantages, as shown by several studies. But solar power is still not widely used in Iraq . The term "photovoltaic" (PV) describes methods for generating DC power from sun radiation . Climate, solar irradiation, season, slanted surfaces, and ambient temperature are some of the variables that affect solar panels' output. Using a basic simulation model, this research measures the efficiency of the output power generator and the efficiency of the solar panels. In addition, the model is updated hourly on-site with data on solar radiation levels, ambient temperature, manufacturing details of the solar module, and the amount of solar radiation hitting the surface panels. Table 3 displays the characteristics and specifics of the photovoltaic panels used in this research. Solar radiation and temperature data were downloaded from NASA[15]. The city of Al-Teeb Area had an average yearly temperature of 22.42 ºC and an average annual solar radiation of 5.03 KWh/m2/d.

II. Wind Turbine (WT)

Generally speaking, Iraq does not have wind speeds high enough to power large-scale wind turbines, with a few exceptions. However, tiny and medium wind turbines may be used in regions with strong enough winds. The kinetic energy of the wind is transformed into electrical energy by means of a wind turbine, which in turn produces electricity. Keep in mind that wind speed is not a fixed number; it changes with the seasons and the hour. When it comes to Iraq, the windiest month is June, which means that wind turbines will be able to generate the most electricity. Table 3 displays the features of a particular wind turbine. All of the wind speed statistics came from NASA, the National Aeronautics and Space Administration. The feasibility of wind energy gathering was determined using the data. the average wind speed in Al-Teeb Area was 5.52 m/s.

III. Diesel Generator (DG)

As mentioned before, a frequent method of delivering power in rural regions is by using a single diesel generator (DG). The benefits of diesel generators, such as their ease of installation and management, are overshadowed by the many disadvantages of the technology. diesel generators contribute to environmental degradation via harmful emissions, consume expensive fossil fuel, incur significant shipping and storage costs, and have high operating and maintenance (O&M) costs. The diesel generator isn't a good long-term option because of all these problems. A major roadblock to the growth of the market for PV-WT hybrid systems is their typically low reliability. Diesel generators have therefore become an appropriate means of increasing the system's dependability. Table 3 displays the details of a particular diesel generator.

IV. Battery Bank (BB)

Batteries are still one of the more costly components of renewable energy systems. Solar and wind power systems rely mostly on battery storage for consistent power delivery, which is why their performance varies. So, the battery is utilized to store power, and the storage energy system is used to save the hybrid system's surplus energy, ensuring a consistent supply of energy. During the deficit phase, the system will produce enough energy to satisfy the load needs. The rated energy capacity, temperature, battery life, depth of charge/discharge, and other factors have a significant impact on battery sizes. When the energy production exceeds the energy load requirement, the hybrid system or a discharging condition would be used to charge the batteries. In Table 3, the specifics of the battery that was used in this research are laid forth.

V. Converter

A key component of the system, the converter transforms the direct current (DC) power from the photovoltaic cells into alternating current (AC) and vice versa; it also converts surplus AC power back into DC for storage in the battery, which may be used when processing power is unavailable. Table 3, displays the specifics of the specific converter employed in this investigation. Those prices for those components were obtained through Homer Pro software due to its direct connection with the global market. Table.3

Table 3. Input parameters. [15]

Parameters	Unit	Value
PV:		
Initial cost	$/KW	1300
Replacement cost	$/KW	1000
O&M cost	$/unit/year	10
Rated power	Watts	1000
Lifetime	Year	25
WT:		
Initial cost	$/KW	18000
Replacement cost	$/KW	17000
O&M cost	$/unit/year	130
Rated power	KW	10
Lifetime	Year	20
DG:		
Initial cost	$/KW	13,000
Replacement cost	$/KW	13,000
O&M cost	$/unit/hour	0.3
Rated power	KW	100
Lifetime	Hours	15,000
BT:		
Initial cost	$/KWh	600
Replacement cost	$/KWh	600
O&M cost	$/unit/year	10
Rated power	KWh	1
Lifetime	Year	10
Converter:		
Initial cost	$/KW	4500
Replacement cost	$/KW	4500
O&M cost	$/unit/year	10
Rated power	KW	20
Lifetime	Year	15
Economic parameters:[16]		
Real interest	%	4
$c_1 = c_2$	-	2
W	-	0.9
N-Ite	-	500

System Lifetime	Year	25

3. Energy management and operation strategy

The research showcased three primary examples of energy management processes for hybrid systems [17].

- The batteries will be charged using excess energy if the overall energy output of the hybrid system is more than the electrical load.
- Instead of using the diesel generator to make up for the shortfall, the batteries will discharge the load to meet the system deficit if the electrical demand surpasses the supply of hybrid power.
- The batteries are empty and the amount of energy produced by renewable sources is insufficient to meet the need. Here, the diesel generator is used to provide the electricity required to fulfil the demand load and to recharge the batteries.

4. Methodology and constraints

Attaining an objective function that considers several limitations, such as optimum size for each system component, high dependability, and renewable energy penetration, is the emphasis of this paper's energy cost optimization efforts [18].

4.1. Cost of energy

One common and popular metric for evaluating the financial feasibility of HRES is the cost of energy (COE) [19]. Everyone agrees that it's the same as the cost of power or the constant price per unit of energy, and here's how to calculate it:

$$\text{Cost of energy (COE)} \left(\frac{\$}{kwh}\right) = \frac{Total\ Net\ Present\ Cost}{\sum_{H-1}^{H-8760} P_{Load}} \text{CRF} \quad (1)$$

TNPC (Total Net Present Cost comprises): all costs (initial, replacement and O&M cost).

$P_{Load}(h)$: hourly power consumption.

CRF: Capital recovery factor. It is computed by:

$$\text{CRF} = \frac{i(1+i)^N}{(1+i)^N - 1} \quad (2)$$

i: Actual interest rate.

N: Lifetime for the system.

4.2 Reliability analysis

One statistical measure that can indicate the likelihood of power outages due to low renewable energy or technical difficulties in meeting demand is the Loss of Power Supply Probability (LPSP). Probabilistic methods can be used to determine the Loss of Power Supply Probability (LPSP), as shown in Equation 3, and reliability (REL), as shown in Equation 4, can be stated as:

$$LPSP = \frac{\sum(P_{load} - P_{pv} - P_{wind} + P_{SOC_{min}} + P_{diesel})}{\sum P_{load}} \tag{3}$$

$$REL = (1- LPSP) * 100\% \tag{4}$$

5. PSO optimization algorithm

Many approaches and algorithms are considered artificial intelligence algorithms nowadays. The particle swarm optimization technique is a widely utilized tool. This approach was created by Kennedy and Eberhart in 1995. The approach has been effectively used in computational intelligence, solving challenging global optimization issues across several scientific domains. Using Particle Swarm Optimization (PSO), particles follow ideal particles in the issue region, promoting population cooperation and competition. Each PSO particle represents a possible solution with two properties: location and velocity. These two variables are adjusted for each particle based on its experience and that of its neighbors. The particles explore the solution region, remembering the goal function value (position). Discovery saves fitness value (P-best). PSO optimizers search the population for additional optimal values. For particles with the best population as topological neighbors, the better value is called the global best (G-best) [20]. Figure. 2 shows the algorithm technique. In this work, the Particle Swarm Optimization approach is used to get optimum outcomes by using particles following the standard formula. This formula aims to find the closest and best particle in a group, considering all particles and following the best one. To accomplish numerous goal functions, this method is used. velocity in its mathematical form are expressed as[21].

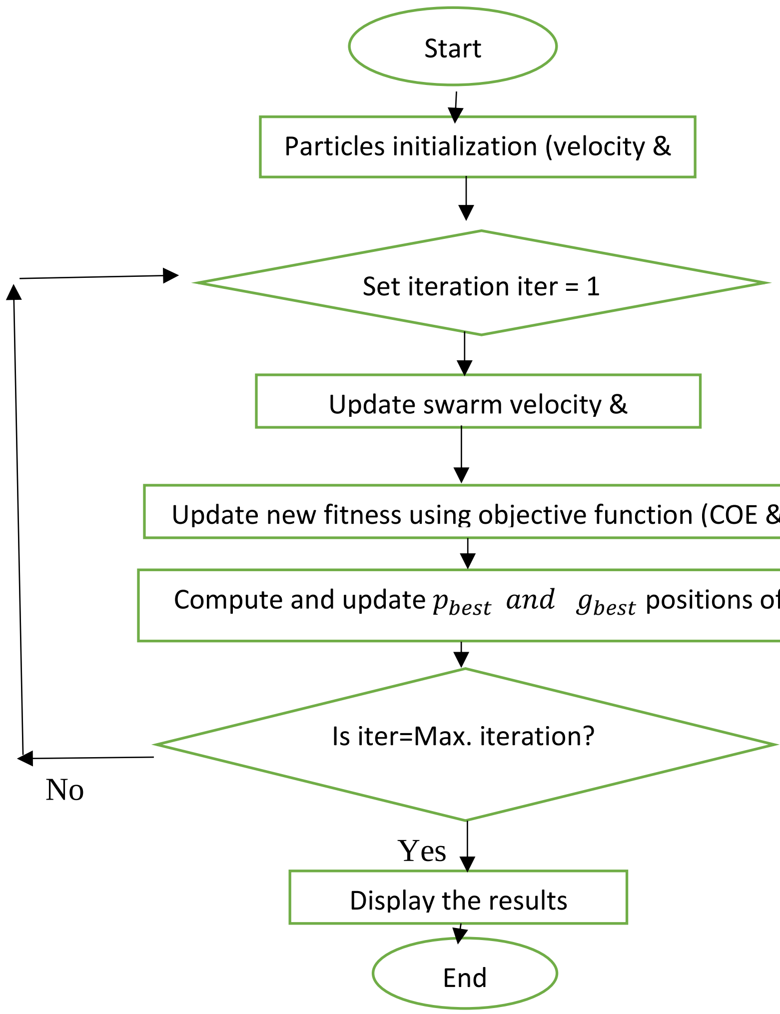

Figure 2. Flowchart of the PSO algorithm.

5.1 Modified PSO (MPSO) or Time Varying Inertia Weight Particle Swarm Optimization (TVIW-PSO)

As early as 1998, Yuhui Shi and Russell Eberhart [22] suggested incorporating a method into PSO. To manage the original PSO's diversification-intensification behaviour, they added a "time varying inertia weight, w (t)" to the fundamental PSO. This is the new rule for velocity updates:

$$v_i^{t+1} = v_i^t + c_1 U_1^t\left(pb_i^t - x_i^t\right) + c_2 U_2^t\left(gb^t - x_i^t\right) \quad (5)$$

$$v_i^{t+1} = \mathrm{w}\,(\mathrm{t}).\, v_i^t + c_1 U_1^t\left(pb_i^t - x_i^t\right) + c_2 U_2^t\left(gb^t - x_i^t\right) \quad (6)$$

$U_1^t \& U_2^t$: are two ***random numbers*** varies between 0 to 1.

From its starting value to its ultimate value, the time-varying inertia weight, w (t), often follows a linear pattern. Parameters $c_1$and c_2 are typically both set to 2[23] . Two methods exist for changing the inertia weight with respect to time. With time-varying inertia weight, the value of the inertia weight varies between iterations. Yuhui Shi and Russell Eberhart coined the term "Dec-IW" [22] to describe a situation in which its values constantly fall. The term "Inc-IW" was first coined by Zheng et al. [24] and describes a situation where the value of w(t) is continually increasing. For Dec-IW, the inertia weight is typically set to 0.9 with a final value of 0.4, while for Inc-IW, it ranges from 0.4 to 0.9. For completeness' sake, both versions are sometimes presented as shown in Fig.3.

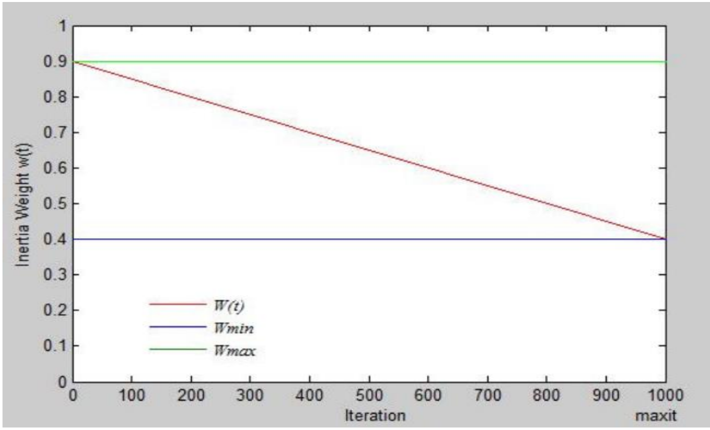

Figure 3. Inertia Weight versus Iteration.[16]

Theoretically, it may be expressed as:

For Dec-IW

$$\text{w (it)} = W_{max} - \frac{W_{max} - W_{min}}{it_{max}} \,.\, it \tag{7}$$

For *Inc-IW,*

$$\text{w (it)} = W_{max} + \frac{W_{max} - W_{min}}{it_{max}} \,.\, it \tag{8}$$

w (it) :The inertia weight changes as the iteration count changes.

W_{max} : The maximum possible inertia weight is 0.9

W_{min} : The minimum possible inertia weight is 0.4

it : Iteration number

it_{max} : The maximum number of Iteration

Furthermore, expression determines position updates[21]:

$$v_i^{t+1} = v_i^t + v_i^{t+1} \tag{9}$$

5.2 Canonical Particle Swarm Optimization

In 2002, a new sort of approach was introduced into Particle Swarm Optimization by Maurice Clerc and James Kennedy [18]. The algorithm's convergence qualities are determined by a combination of many factors. They added a "Constriction Factor (X)" to the standard PSO to regulate the particles' convergence characteristics. Once the Constriction Factor (X) is included, the formula for updating velocities becomes:

$$v_i^{t+1} = X(v_i^t + c_1 U_1^t (pb_i^t - x_i^t) + c_2 U_2^t (gb^t - x_i^t\ )\ ) \quad (10)$$

Where: X = $\frac{2k}{(|2 - Q\sqrt{(Q^2 - Q)}|)}$

Here c_1 is the "cognitive parameter" and c_2 is the "social parameter", k is a random number which varies from 0 to 1, i.e. k ∊ $[0,1]$, Q = c_1 +c_2 and Q should be greater than 4. Generally, k is set to 1 and both c_1 & c_2 are set to 2.05, giving as a result X equal to 0.729.

5.3 Self-Organizing Hierarchical PSO with Time-varying Acceleration Coefficients (HPSO-TVAC)

In their original publication, Ratnaweera et al. [25] presented this method. He removes the velocity component from the time-varying inertia weight equation's right-hand side. Using this method, they suggested a new formula for updating velocity as:

$$v_i^{t+1} = c_1 U_1^t (pb_i^t - x_i^t) + c_2 U_2^t (gb^t - x_i^t\ ) \quad (11)$$

The acceleration coefficients, however, follow a pattern similar to that of TVAC-PSO; that is, c_1 fluctuates between 2.5 and 0.5, while c_2 fluctuates between 0.5 and 2.5, as shown in the equations. A particle's new velocity is reinitialized to a value corresponding to the maximum permissible velocity Vmax if it reaches 0 in any dimension during the velocity computation. Last but not least, the re-initialization of velocity is likewise reduced linearly from Vmax at start of run to (0.1*Vmax) at finish. You may get a general idea of the PSO optimization method from the preceding explanation. The optimization of the suggested hybrid system, which will be covered in the future chapter, was done using a Stochastic Inertia Weight PSO approach.

6. Results and discussion

The following location-specific variables and data were entered: solar radiation, temperature, wind speed, available PV size, WT, DG, and BT; project lifetime; project coordinates; price details (including initial cost (IC), replacement cost (RC), O&M), and the number of components of the hybrid power system), etc. The typical yearly energy consumption for a load profile is approximately 20,720.882 kWh/day. Various operation modes were implemented as part of the power management strategy for the Hybrid Micro Grid System (HMGS) to provide a continuous supply of power regardless of the load demand. To find the fastest option for the site, extensive techno-economic study was carried out. Therefore, to examine the proposed systems from an economic perspective, we used the Cost of Energy (COE) indicator. From a technical one, we used the Loss of Power Supply Probability (LPSP) and Reliability (REL) indicators. Finally, from an environmental perspective, we used the Renewable Energy Penetration (REP) indicator. Finding the best solution for optimization problems using the Particle Swarm Optimization technique requires a precise representation of the target function and its restrictions in each particle. Particles in each swarm start with arbitrary location and velocity values according to all limitations (minimum and maximum hybrid components, reliability, etc.) and (PSO) characteristics. One population is used in this study, and each population undergoes 500 rounds of swarm motion. We thought 500 iterations was the upper limit for each population. After that, we updated the location and velocity values every time, kept the best ones, and ignored the bad ones. When the total number of iterations hit the maximum value, the search ended.

Reliability and the maximum potential value of renewable energy penetration with minimum expense are the primary goals of the optimal solution configuration of a hybrid renewable energy system (HRES). Based on the probability of power supply loss (LPSP), the reliability (REL) is calculated. The results demonstrated a low cost of energy (COE) of (0.117 US$/KWh), a very strong penetration coverage of renewables of (18 %), and a very high reliability of the hybrid system of (79.35%), all achieved by (PSO) optimization techniques. The most ideal configuration for a Hybrid Renewable Energy System (HRES) was determined to be NPV(1235), NWT(58), NDG(12), NBT (3112) and NC(46) according to the data in Table 4 and Figures (4,5,6,7,8). In this investigation, the global optimal point was reached at the iteration number of 4465. Table 3 displays the percentage of energy generated each year by PVs, WTs, and DGs. The development of such systems can be complex and difficult because the optimal combinations are found at distant points with the same fitness value and different configurations in the objective domain. Based on factors including location and availability of energy sources, as well as the system designer's desires, needs, implementation, creation, and expansion of existing systems, the system designer is assigned the ultimate optimal solution.

Table 4. Comparison of the results obtained among types of PSO algorithm.

N	Station	abbreviation	MPSO or TVIW-PSO	Canonical-PSO	HPSO-TVAC
1	Number of Photovoltaics	NPV	1235	1229	1243
2	Number of Wind Turbines	NWT	58	56	56
3	Number of Diesel Generators	NDG	12	12	12
4	Number of Batteries	NBT	3112	3125	3120
5	Number of Converters	NC	46	47	47
6	Cost of Energy($/KWH)	COE	0.117	0.119	0.118
7	Loss Power Supply Probability	LPSP	0.2065 %	0.2077 %	0.2010 %
8	Number of Global Best	NGB	4464	4469	4478
9	Renewable Energy Penetration	REP	18.00 %	18.11 %	17.54 %
10	Reliability	REL	79.35 %	79.23 %	79.88 %
11	Annual energy provided by PV		0.28 %	0.28 %	0.28 %
12	Annual energy provided by WT		29.48 %	29.48 %	29.48 %
13	Annual energy provided by DG		21.91 %	21.91 %	21.91 %
14	Total Net Present Cost (Million $)	TNPC	9.36	9.47	9.42

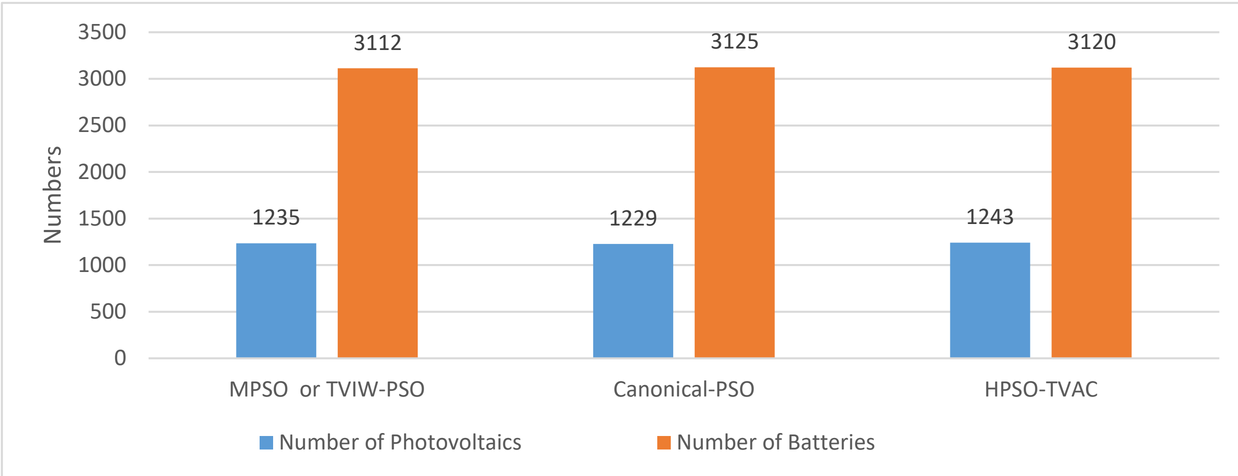

Figure 4. Comparison of the numbers of photovoltaics and bank batteries obtained among types of PSO algorithm

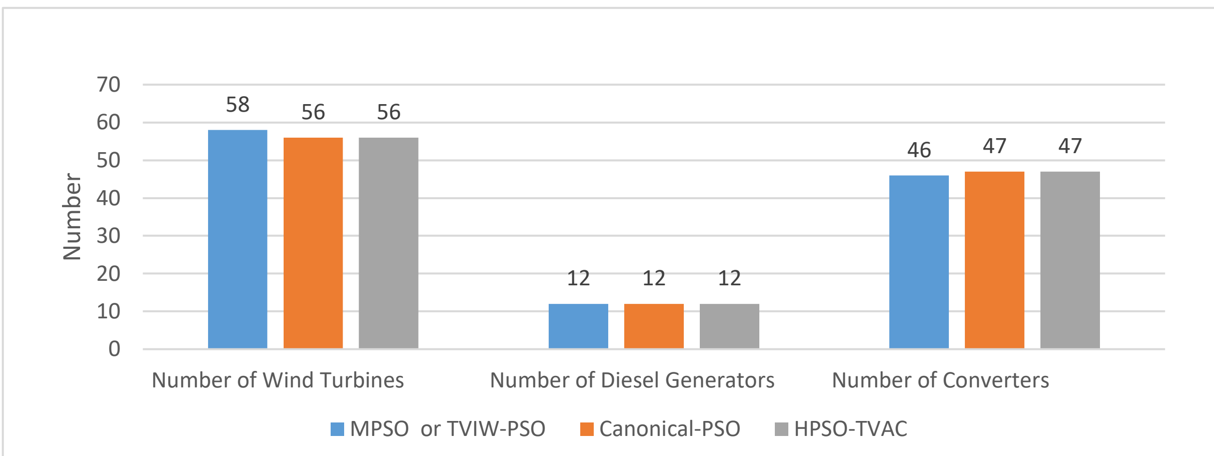

Figure 5. Comparison of the numbers of wind turbines, DG and converters obtained among types of PSO algorithm

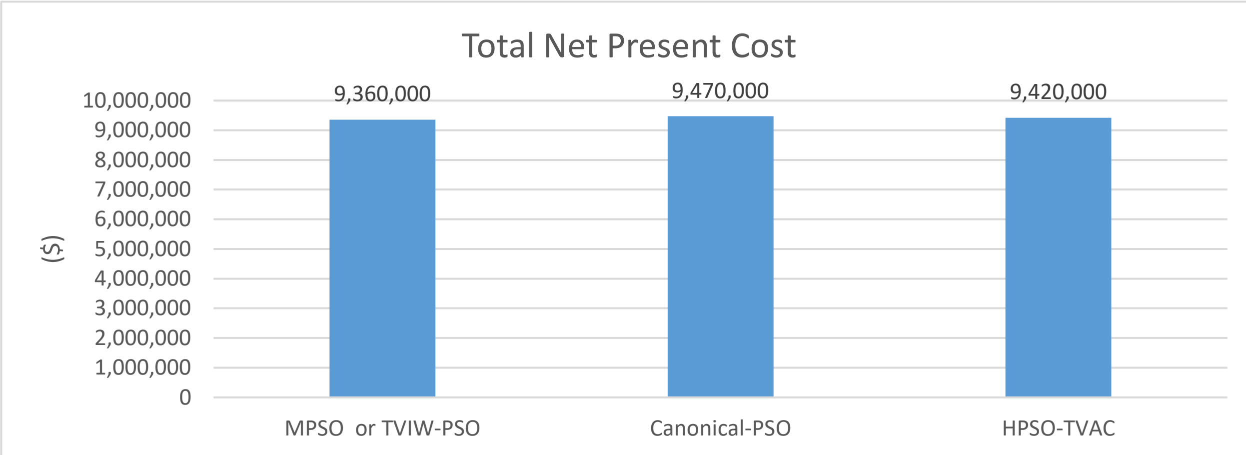

Figure 6. Comparison of the total net present cost among types of PSO algorithm

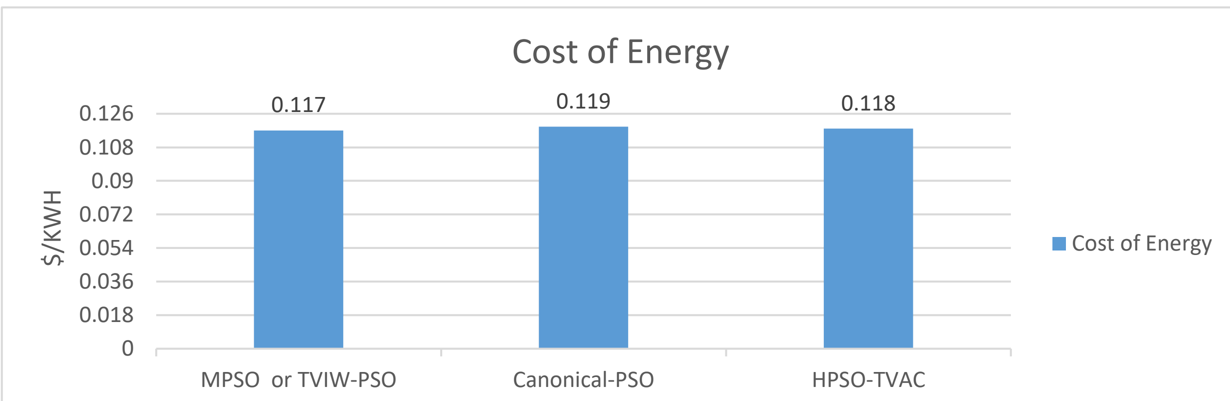

Figure 7. Comparison of the cost of energy among types of PSO algorithm

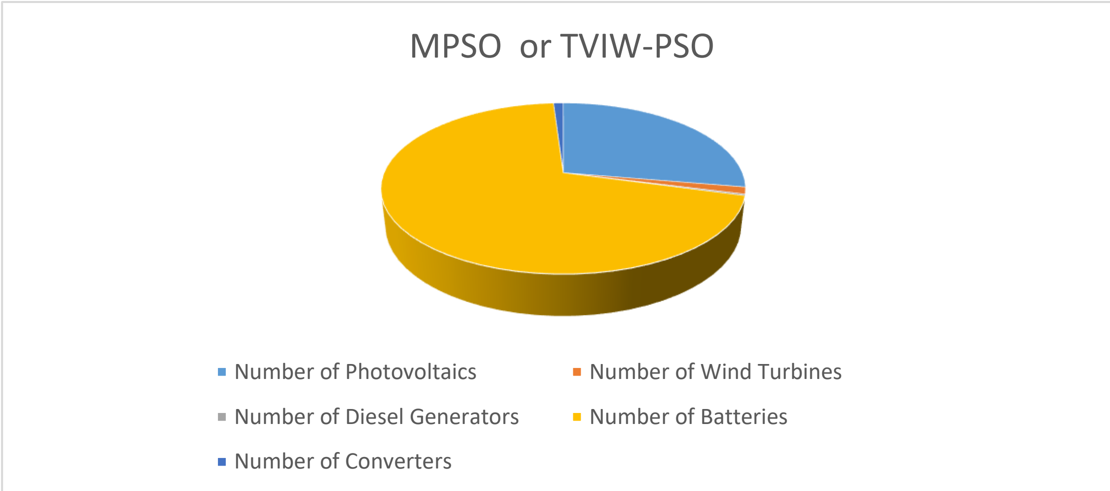

Figure 7. Comparison of the results obtained among type of MPSO or TVIW-PSO algorithm.

7. Conclusion

The availability of reliable electricity continues to be a crucial need for modern communities. In addition to improving the local economy, electrification can improve people's quality of life by expanding their access to healthcare and educational opportunities.

In order to increase the electricity supply while decreasing installation costs, microgrids could be a viable option for usage in outlying regions. Located in southeastern Iraq, near the Iranian border, the city of Al-Teeb Area was the site of the current investigation. In this study, we look at a global solution to size optimization, economics, energy management, and expansion plans for many hybrid energy systems in regions where we can theoretically simulate factors like electrical load, location, temperature, wind speed, and solar radiation. Particle Swarm Optimization (PSO) has been utilized in numerous research for multi-objective functions due to its advantages in reaching optimal solutions. An optimization algorithm was developed in MATLAB with a defined objective function of Cost of Energy (COE) and Loss of Power Supply Probability (LPSP). Three different types of PSO algorithms were utilized,(**MPSO, Canonical-PSO and HPSO-TVAC**) and the results from the first type of PSO algorithm were found to be the most suitable for implementing this system in terms of Cost of Energy (COE) and Total Net Present Cost (TNPC). The three cases were discussed in detail through their outcomes, and it was observed that all of them integrate the main components of the system, represented by (PV-WT-DG-BB and Con), to supply the electrical load for the Al-Teeb Area entirely and ensure load stability from that generation. The primary criteria for selecting the type of PSO algorithm were the Cost of Energy (COE) and Total Net Present Cost (TNPC) as mentioned above. It became clear that the first type of PSO algorithm is the best for implementing this system.

Throughout its 25-year lifespan, this project gathered weather data for the Al-Teeb Area from the National Aeronautics and Space Administration (NASA). A stand-alone Hybrid Renewable Energy System (HRES) project's energy cost needs to be minimized while taking numerous constraints into account, including renewable energy penetration (REP), high reliability (REL), high efficiency, and expansion for future development.

This study portrayed the economic problem in this regard. To solve the objective functions of any nonlinear

and difficult issues and find a global solution, the findings demonstrated that the modified particle swarm optimization technique is highly capable and incorporates various parameters. Using a Hybrid Micro Grid System (HMGS) will lead to a high Renewable Energy Penetration (REP) value, according to optimization results. Thus, increasing the availability of electricity in rural areas of Iraq through the use of renewable energy sources can raise living standards.
Furthermore, there are several benefits to generating energy utilizing wind turbines, one of which is higher economic profitability compared to PV panels. There are some technical hurdles that prevent microgrid initiatives from being implemented, but the suggested method can overcome them all. Additionally, the study's findings can be used as a foundation or a tool to propel initiatives for remote electrification and speed up the design and execution of different projects.

Some common limitations in research studies that other researchers might address:

1. Sample Size: A small sample size can limit the generalizability of the results. Future research could use a larger, more diverse sample.
2. Sampling Bias: If the sample is not representative of the population, the findings may not be widely applicable. Researchers could use more rigorous random sampling methods.
3. Study Design: Limitations in the study design (e.g., observational vs. experimental) can affect the ability to infer causation. Future studies could employ more robust experimental designs.
4. Measurement Tools: If the tools or instruments used to measure variables are not reliable or valid, the results may be questionable. Researchers could use or develop more precise measurement tools.
5. Confounding Variables: Uncontrolled confounding variables can impact the study's findings. Future research could control for or account for these variables more effectively.
6. Temporal Limitations: Studies conducted over a short period may not capture long-term effects. Longitudinal studies could address this limitation.
7. Geographic and Cultural Limitations: Results from one geographic or cultural context may not be applicable to others. Future research could include multiple sites or diverse cultural settings.
8. Self-Report Bias: If the study relies on self-reported data, responses may be biased. Using objective measures or multiple data sources could mitigate this issue.
9. Ethical Constraints: Certain ethical considerations may limit the scope of a study. Future research could find ethically appropriate ways to address these limitations.
10. Technological Limitations: The technology or methods used might be outdated or less effective. Researchers could use more advanced or appropriate technology.

Nomenclature is included if necessary			
		NWT	Number of Wind Turbines
		NDG	Number of Diesel Generators
PSO	Particle Swarm Optimization	NBT	Number of Batteries
MPSO	Modified Particle Swarm Optimization	NC	Number of converter
HRES	Hybrid Renewable Energy System	IC	Initial Cost
HES	Hybrid Energy System	O&M	Operating and Maintenance cost
HS	Hybrid System	CRF	Capital Recovery Factor
RE	Renewable Energy	i	Real interest rate
HMGS	Hybrid Micro Grid System	N	Lifetime for the system
COE	Cost of Energy	c1	Cognitive parameter
REP	Renewable Energy Penetration	c2	Social parameter
PV	Photovoltaic	r1	Random number between 0 and 1
WT	Wind Turbine	r2	Random number between 0 and 1
DG	Diesel Generator	W	Inertia weight ($0 < w < 1$)
BT	Battery	EL	Load (KWh)

C	convertor	P(t)	Generated power (KW)
NPV	Number of Photovoltaics	NPOP	Number of Populations
TNPC	Total Net Present Cost	N-Ite	Number of iterations
HPSO-TVAC: Hierarchical PSO with Time-varying Acceleration Coefficients		M	Million
		GHG	greenhouse gas

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