**TELKOMNIKA**, Vol.16, No.5, October 2018, pp. 2331~2341
ISSN: 1693-6930, accredited First Grade by Kemenristekdikti, Decree No: 21/E/KPT/2018
**DOI:** 10.12928/TELKOMNIKA.v16i5.8897 

# Techno-economic Viability and Energy Conversion Analysis of RHES with Less Weight/Area

**Mohammed Kdair Abd*[1], Hadeel Nasrat Abdullah[2], Haishun Sun[3], Shijie Cheng[4]**
[1,2]Department of Electrical Engineering, University of Technology, Baghdad, Iraq
[3,4]School of Electrical & Electronics Engineering, Huazhong University of Science & Technology, Wuhan, Hubei Province, China
*Corresponding author, e-mail: 30098@uotechnology.edu.iq

***Abstract***

*This article proposes a new strategy to find the optimal location, configuration and size of the Renewable (wind-photovoltaic-diesel-battery) Hybrid Energy Systems (RHES (off-grid)). This study has two steps: first, the proposaltoa strategybased on a weather change to find the optimal location in Iraq using Hybrid Optimization Model for Electric-Renewables (HOMER) software. Second, the study will examine the influence of the techno-economic viability from side less weight and area on the optimal configuration/size of the RHES, which gives the maximum output power. A period of one-year for meteorological data for both solar radiation and wind speed has used. Finally, simulation results indicated that the optimal location for this RHES is the AL Harithah location. The analysis has shown that RHES can supply 89% of the load demands by renewable-energy. It is also successful in reducing the area required for installation of the RHES about 28%.*

***Keywords***: *techno-economic, net power cost (NPC), renewable, cost of energy (COE)*



## 1. Introduction

There is a difficulty with transporting fuel to remote and rural places, non-arrival of electric power to these areas, in addition to the annual increase in population ratios and increased pollution in the atmosphere. All of these factors led to the emergence of renewable-energy-sources. At present, many countries have directed research into alternative sources of conventional electric power, due to concerns about the global climatic change and fluctuating fuel prices, searching for reliable and green sources. In Iraq, the electricity generated is not enough to meet the load demands. By using Genetic algorithms and Matlab software, Reference [1] propose using hybrid renewable resources of power generation connected to the grid and also selecting the location size of Photo-Voltaic (PV) and Wind Turbine (WT) in threecities in Iraq [2].

The electrical loads in the Iraq power grid containa significant proportion of the residential load. In [3] proposed supplying part of the residential-load in the Mosul location using a hybrid system. References [4–6], proposed to determine high the renewable fraction and less the greenhouse gases emissions using economical and the environmental analysis of net-zero energy for tourist village. In Homer software, there are several indicators for the purpose of selecting the optimal design and size of the standalone such as *NPC*, *COE*, full consumption saving, capital cost, replacement cost, operation and maintenance (*O&M*) cost of Diesel generators (Dg), $CO_2$-emission and pollutants and lifetime [7, 8]. These indicators are used to find the type and size of the hybrid system of renewable energy sources that give the best performance [9, 10]. It considered that Distributed Generation Technologies based on the renewable energy of essential technologies, called standalone hybrid renewable energy system [11-13], can be suitable options for remote and rural areas [14-17].

Several authors show the optimization of standalone hybrid renewable systems, analyse the application of WT, PV and Dg and reducing the *NPC* of the system [18–21]. In addition to, reference [22] proposed creation of the best configuration of a plant based on renewable energies to operate the oil rigs, which sometimes located in remote areas or the sea and also when away from the electrical grid. References [23, 24] presents a hybrid system from the perspective of the optimisation and management of the system. The problem of the weight

*Received February 7, 2018; Revised June 23, 2018; Accepted July 15, 2018*

of the equipment is fundamental in the transport process, where in some cases the transportation of the components and fuel from the manufacturing site to the work site is tricky. Also, the transport cost is expensive, due to the difficult and dangerous of the roads.The transport cost by trolley varies in each country, and it depends fundamentally on the kind of road and the fuel price. In addition to, the problem of the area isessential in decreasing area for installation of RHES equipment, which in turn will reduce the total cost and also the collision probability of the migratory birds with wind turbine fins.

However, these methods consist ofa drawback concerning the less weight and area using HOMER software. All the above mention methods have focused only on cost estimation, maximise human development index, use different battery technologies, *NPC*, *COE*, fuel cell and power management. These methods do not take into considerationless weight and area of the system, plus that negligence of the weight and area will cause an increase inthe cost of construction and generation of the energy. In Iraq, the abundant solar radiation and wind are not tapped into properly, because of the high cost and the lack of a variety of studies on this topic. This paper has two steps: First step: proposed of planning to choose the best location for the installation RHES (off-grid) in the remote areas based on a weather changes. The system consists of 400 houses with five capita per house. The average consumption per capitaof power about (1.639 kWh) [25] and the average consumption per household about (8 Kwh). For simulated, we took twelve locations in our country (Iraq) and divided into three regions. Second step: Study the techno-economic viability fromside less weight and area on the optimal configuration and size of the RHES (off-grid) using HOMER software.

## 2. Location and Meteorological Data

The meteorological data (global solar radiation, wind speed), were measured at twelve locations in Iraq for every month of the year 2016 [26].
The locations in Iraq were divided into three regions and showed as follows:

a. The northern region: Four locations and includes: Mosul, Chamchamal, Bayji and Erbil.
b. The middle region: Four locations and includes: Baghdad, Abu Ghraib, Samarra and AL Suwayrah.
c. The southern region: Four locations and includes: AL Basrah, AL Nasiriyah, AL Amarah and AL Harithah.

The geographical coordinates of the Iraq data collection site were latitudes 33.3333° N, and longitudes 44.4333° E. Figure 1, shows the three geographical regions in Iraq [26, 27].

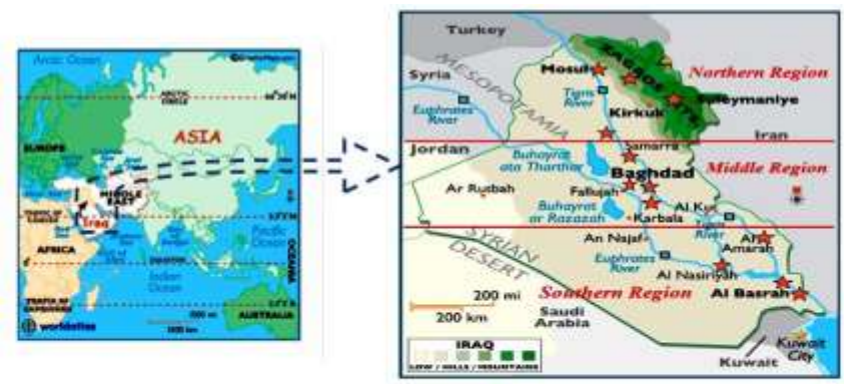


Figure 1. The three geographical regions in Iraq

## 3. Methodology & Proposed Hybrid Model

In this paper, the methodology used for simulation and modelling purposes is Electrical Renewable (HOMRE) software. The proposed hybrid model is a design using HOMRE and consists of WT, PV, Dg, battery and power-converter; Figure 2 shown this model implementation. HOMER is a design model that determines the optimal-configuration, control-strategy and feasibility-study of the hybrid system. HOMER needs the information data such as wind speed data, solar radiation data, load data, costs, economic and emission constraints [28, 29], described as follows:


Figure 2. Hybrid model (off-grid) in HOMER

### 3.1. Wind Speed Data

The primary resource for the hybrid model is the wind. The wind speed data presented graphically in Iraq in the northern region, middle region and the southern region in Figures 3, 4 and 5, respectively [25]. We can note that the variation between the monthly averages of wind speed is essential; the abundant months are indeed those of May (5.556 m/s), July (5.278 m/s) and August (5.278 m/s) for the northern region, June (14.806 m/s), July (15.806 m/s) and August (14 m/s) for the middle region and June (16.611 m/s), July (15.5 m/s) and August (13.694 m/s) for the southern region. On the other hand, for January, March, November and December for the northern region, the wind speed does not exceed 4 m/s. For better performance of a wind turbine, there must be a wind speed in the range of 4 to 8 (m/s). Can be considered unsuitable for conversion systems of wind speed (if the wind speed average is stable, there will be a guarantee for the generation of stable electrical power).

### 3.2. Solar Radiation Data

The second resource for the hybrid model is the sun. The solar radiation data are collected from [25] and shown in Figures 6, 7 and 8 for the northern, middle and southern region in Iraq, respectively.Average global solar radiation in Iraq is almost up to 8 (kW/m$^2$) because it locates within the equatorial zone. The figures above illustrate that solar radiation is more than 6 (kW/m$^2$) from May to August in all regions of Iraq, but the southern region has the highest rate of solar radiation. However, in June and July, various regions in Iraq show similar levels of radiation and hence constitute a vast potential for solar energy generation.

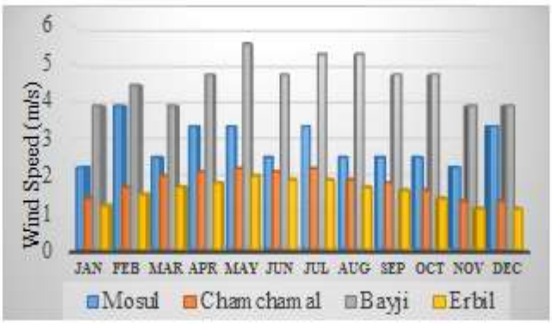


Figure 3. Monthly average wind speed in the northern region

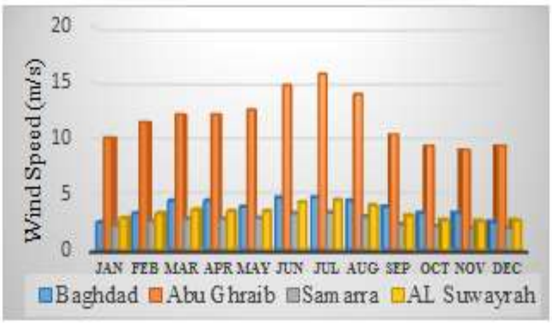


Figure 4. Monthly average wind speed in the middle region

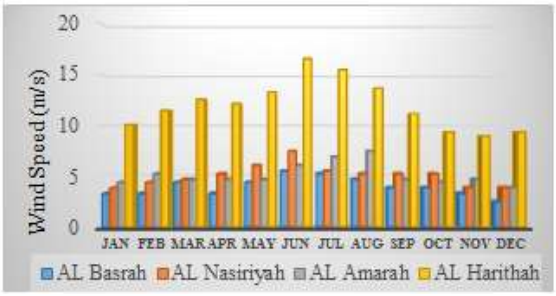


Figure 5. Monthly average wind speed in the southern region

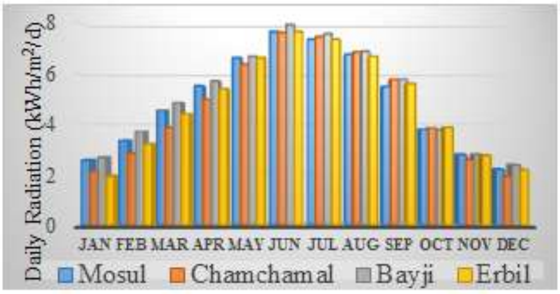


Figure 6. Monthly average daily solar radiation in the northern region

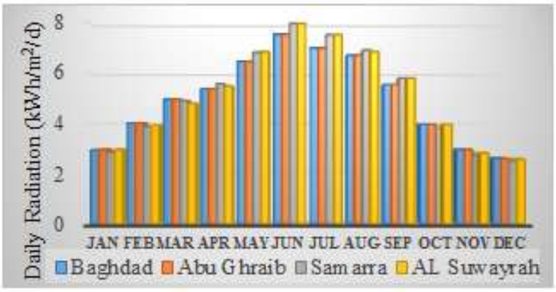


Figure 7. Monthly average daily solar radiation in the middle region

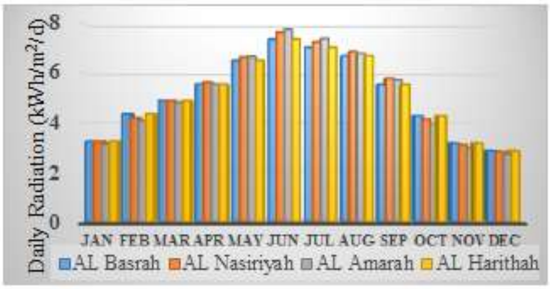


Figure 8. Monthly average daily solar radiation in the southern region

### 3.3. Diesel Generator

Diesel generators are used as backup power sources and are being developed to increase the reliability and stability of the electric power when the WT/PV hybrid system is not able to produce enough electrical power to meet the load demand. Therefore, Dg was used widely with the renewable hybrid energy system to increase the reliability and stability of the system [24].

### 3.4. Batteries and Inverter

Because of the climatic changes and the intermittent nature of the wind and the solar radiation, there is a need to use battery storage facilities to ensure steady power supply. Also, the inverter is used to convert the DC power produced by PV or wind to AC power (some units of wind power produce DC power, others produce AC power). In this study, Homer software is applied to simulate (WT, PV, Dg, Batteries and power-converter) hybrid system. Homer will calculate the different permutations of possible designs based-on inputs provided and simulate the system. The area of the WT and PV panel isan estimate in 1020 ($m^2$) and 22 ($m^2$ for 1kW), respectively. The input data are briefly described in Table 1 [11, 12, 14, and 24].

Table 1. Input data of Homer software

| Items | WT | PV | Dg | Battery | Converter |
|---|---|---|---|---|---|
| Available Sizes | Generic 10 kW | 100, 200, 300, 500, 700, 1000, 1200 kW | 300, 400, 500 kW | Generic 1KW Lead Acid (12V,8383400Ah) | 100, 200, 300, 400, 500 kW |
| Quantity | 20, 50, 75, 100, 120 | --- | 1 | 20, 40, 50, 80, 100, 120 | --- |
| Capital Cost | 15000 $/turbine | 3500 $/kW | 1500 $/kW | 300 $/kW | 200 $ |
| Replacement cost | 12000 $/turbine | 2500 $/kW | 1200 $/kW | 280 $/kW | 200 $ |
| *O&M* Cost | 50 $/turbine .yr | 30 $/kW/yr | 0.02 $/hr | 10 $/hr | 10 $/yr |
| Life-Time | 20 yr | 25 yr | 15000 hr | 10yr | 15 yr |

**4. Mathematical Model**

The RHES (off-grid) location problem has formulated as an objective minimisation problem. The matrix constrained has been used to formulate the planning problem. Mathematically, the first step in this paper, the multi-objective function and constraints can be formulated as follows:

$$\text{Min}\left\{ f1=\left( \alpha 1*\frac{COE}{COE_{base}}+\alpha 2*\frac{NPC}{NPC_{base}}+\alpha 3*\frac{fren_{base}}{fren} \right) \right\} \tag{1}$$

$$\alpha 1+\alpha 2+\alpha 3=1 \tag{2}$$

We can find the (*α1*, *α2*, *α3*) by using the matrix:

$$\begin{bmatrix} \alpha 1 & \alpha 2 & \alpha 3 \end{bmatrix}=\begin{bmatrix} 1 & 0 & 0 \\ \vdots & \vdots & \vdots \\ 0 & 1 & 0 \\ \vdots & \vdots & \vdots \\ 0 & 0 & 1 \end{bmatrix} \tag{3}$$

where:

$$\left. \begin{matrix} 0 \le \alpha 1 \le 1 \\ 0 \le \alpha 2 \le 1 \\ 0 \le \alpha 3 \le 1 \end{matrix} \right) \tag{4}$$

The second step, the RHES (off-grid) planning problem has formulated as a multi-objective minimisation problem. The multi-objective function is minimising the cost and weight system, formulated as follows:

$$\text{Min}\left\{ f_2=\left( \alpha 1*\frac{COE}{COE_{base}}+\alpha 2*\frac{\text{MinW}_{TOT.}}{\text{MinW}_{TOT.base}}+\alpha 3*\frac{fren_{base}}{fren} \right) \right\} \tag{5}$$

The total system weight ($W_{TOT}$ ), we can formulate as follows:

$$MinW_{TOT.}=W_{WT.}+W_{PV.}+W_{Dg.}+W_{Batt.}+W_{Conv.}+W_{FUEL} \tag{6}$$

$$W_{FUEL}=\sum_{t}^{8760} FL_t*DOF \tag{7}$$

Moreover, the total system area for WT, PV ($A_{(WT,PV)}$) formulated as follows:

$$A_{(WT,PV)}=A_{WT.}*No.\ of\ WT+A_{PV.}*Size\ of\ PV_{(kW)} \tag{8}$$

Where: $W_{WT}$ is the weight of the WTs. $W_{PV}$ is the weight of the PV panels, $W_{Dg}$ is the weight of the distributed generations, $W_{Batt}$ is the weight of the batteries. $W_{conv}$ Is the weight of the power-converters, $W_{FUEL}$ is the weight of the fuel, $FL$ is numbers of the fuel litres, $DOF$ is the density of the fuel (kg/cm$^3$), $A_{WT}$ is an area of the WT (m$^2$), and $A_{PV}$ is the area of PV (m$^2$).

The *NPC* of a hybrid model is the present value of all the costs of installing and operating that component over the project lifetime. The costs include capital/costs, replacement-costs, *O&M* costs, fuel/costs and emissions. The revenues include salvage value and grid sales. HOMER calculates the *NPC* by summing up the total discounted cash flows in each year of the project lifetime using the following equation [17, 28]:

$$NPC=\frac{TAC}{CRF(i,k)} \tag{9}$$

To calculate the total annualised cost (*TAC*) use the following equation:

$$TAC=C_{acap.}+\sum_{i=1}^{m} C_{OM,i}+C_f+\sum_{j=1}^{m} C_{R,j} \tag{10}$$

where: *CRF* is the capital recovery-factor, shown in the equation below:

$$CRF(i,k)=\frac{i(1+i)^k}{(1+i)^k-1} \tag{11}$$

The real discount-rate ($i$) is used to convert between one-time costs and annualised costs. HOMER uses the following equation to counting the real discount-rate:

$$i=\frac{i'-f}{1+f} \tag{12}$$

where: $i'$ is nominal discount-rate, and $f$is expectant inflation-rate.

To calculate the *COE*, HOMER divides the annualised cost of producing electricity (the *TAC* minus the cost of serving the thermal load ($C_{boiler}H_{served}$) by the total electric load served ($E_{served}$), using the following equation:

$$COE=\frac{TAC-C_{boiler}H_{served}}{E_{served}} \tag{13}$$

The second term is equal to zero, at no thermal load on the system. The remaining value in a component of the power system at the end of the project lifetime called the salvage-value (*S*), assumes linear depreciation of components. It also depends on the replacement-cost rather than the initial-capital cost [28, 29]. We can calculate the *S* using the following equation:

$$S=C_{rep}\cdot\frac{R_{rem}}{R_{comp}} \tag{14}$$

Where $R_{rem}$ is the remaining/life of the component at the end of the project lifetime, is shown as follows:

$$R_{rem}=R_{comop}-(\mathrm{R}_{proj}-R_{rep}) \tag{15}$$

Moreover, the replacement-cost duration ($R_{rep}$), is shown as follows:

$$R_{rep}=R_{comp}.INT\left(\frac{R_{proj}}{R_{comp}}\right) \tag{16}$$

The operating-cost ($C_{oper.}$) is the annualised value of all costs and revenues other than initial capital costs, the $C_{oper}$ value defined as follows:

$$C_{oper.}=TAC-C_{ann,cap} \tag{17}$$

Where: $K$ is a number ofthe years, $C_{rep}$ is replacement cost ($), $R_{comp}$ is component life-time (yr), $R_{proj}$ is projected lifetime (yr), *INT* is a function that returns the integer amount of a real number, and $C_{ann,cap}$ is the total annualised capital cost ($/yr).

## 5. Simulation and Results

### 5.1. Optimal Location of RHES in Iraq

The proposed hybrid model in Figure 2 has been designed and simulated with the use of HOMER software. To find the optimal location for the installation RHES (off-grid), we took twelve locations in Iraq. A strategy has been proposed based ona weather-change to find the optimal-location. The planning load average of consumption per household about 8 (kWh), the average daily demand was 133.3 (kWh), and the average monthly consumption shown in Figures 9 and 10.

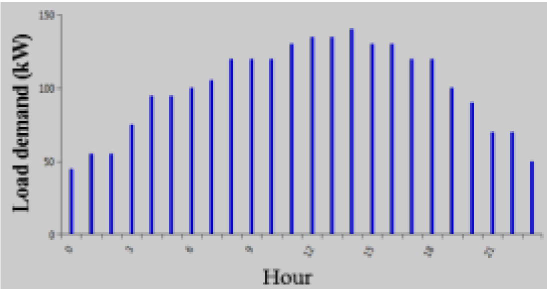


Figure 9. Daily load demand

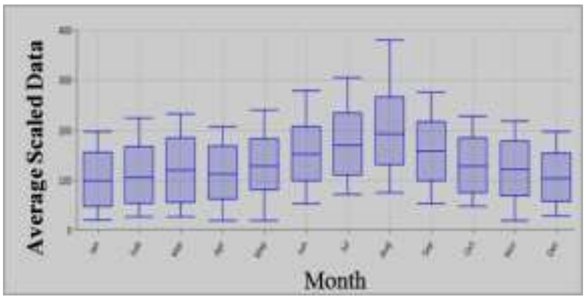


Figure 10. The average load of every month

The renewable fraction ($f_{ren}$) also studied in this paper. The $f_{ren}$ is the fraction of the energy delivered to the load that originated from renewable-energy sources [28]. Table 2 shows the results with the $Minf_1$ to select the optimal location in Iraq. The results show that the optimal location to build a hybrid system in the northern region is the Bayji location, in the middle region it is the Abu Ghraib location, and in the southern region, it is the AL Harithah location. Also, it is clear that the optimal location to build RHES (off-grid) in Iraq is the AL Harithah location, which is regarded as an excellent location at $Minf_1$ (0.1320), less *COE* and *NPC* with high penetration rate (86%).

Table 2. Results of the $Minf_1$ for twelve locations in Iraq

| Locations | *COE* ($) | *NPC* ($) | *fren* % | $Minf_1$(p.u) |
|---|---|---|---|---|
| Mosul | 0.781 | 20.3M | 69 | 0.7826 |
| Chamchamal | 0.899 | 23.4M | 54 | 1 |
| Bayji | 0.433 | 11.2M | 88 | 0.4786 |
| Erbil | 0.869 | 22.6M | 57 | 0.9473 |
| Baghdad | 0.563 | 14.6M | 80 | 0.6239 |
| Abu Ghraib | 0.121 | 3.14M | 86 | 0.1341 |
| Samarra | 0.780 | 20.3M | 69 | 0.7826 |
| As Suwayrah | 0.633 | 16.4M | 80 | 0.675 |
| AL Basrah | 0.509 | 13.2M | 84 | 0.5641 |
| AL Nasiriyah | 0.365 | 9.50M | 89 | 0.4059 |
| AL Amarah | 0.347 | 9.02M | 91 | 0.3854 |
| AL Harithah | 0.119 | 3.09M | 86 | 0.1320 |

**5.2. Optimization Analysis of the AL Harithah Location**

This section will examine the techno-economic viability of the optimal configuration and size of the RHES (off-grid) using HOMER software. This analysis aims to assess the techno-economic viability of four cases arrangement for AL Harithah location (all cases shown in Figure 11), including all possible combinations of WT, PV, Dg, power converter and batteries to determine the best configuration and size for electrical output power in each case as follows: Case 1: (WT+Dg), Case 2: (PV+Dg), Case 3: (WT+PV), Case 4: (WT+PV+Dg)

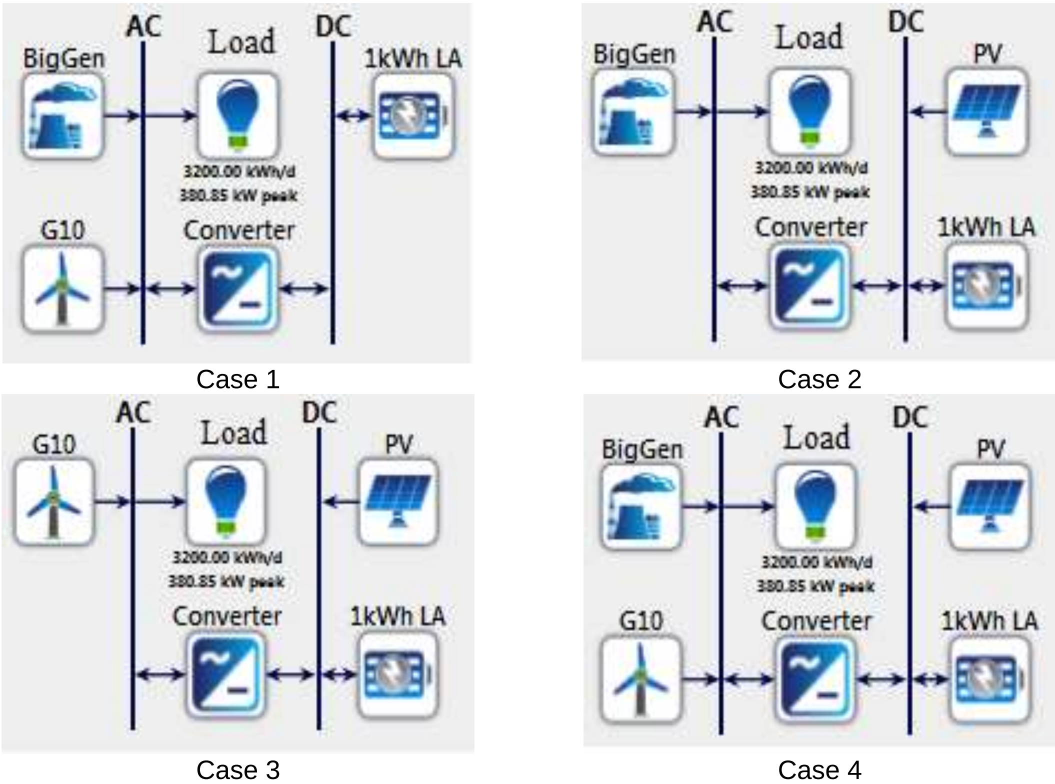


Figure 11. Different RHES (off-grid) configuration in HOMER

In this study, use two sensitivity factors in the system analysis with the adoption of the less weight and area to determine the optimal configuration and size of the RHES. The first factor, capital-cost multiplied by (0.6, 0.8, and 1). The second factor, replacement-cost multiplied by (0.6, 0.8, and 1). The optimal system designs obtained from the simulation of cases 1 to 4 for each considered community presented in Tables 3 and 4. It can be in these tables that to compare the configurations and size for weight minimisation, the resulting yearly for $W_{TOT.}$, *COE*, *fren*and $Minf_2$ for each case has determined. The total yearly output power produced by each generation type (WT+PV+Dg) is also computed. Therefore, the analysis essence of economic, weight minimisation and less area is to find the most economically suitable cases for the AL Harithah location. From the viewpoint of the weight minimization analysis, Tables 3 and 4shown the minimum weight and $Minf_2$ values for case 4 comparison with cases (1, 2, and 3). The case 4 (WT+PV+Dg) is the most savingdesign for the AL Harithah location. Also, we can see from Table 4 (cases 3 & 4) that renewable energy supplies the maximum part of the electrical load, while the case 3 configuration achieved 100% renewable energy but with increased weight and $Minf_2$.

From the viewpoint of the techno-economic viability analysis, we used two sensitivity factors of the analysis with the adoption of the weight minimisation. The case 4 the optimal configuration case with capital cost multiplier by (0.8) and replacement cost multiplied by (1). Where $Minf_2$ and weight are 0.26411 (p.u.) and 68.879 (*ton*) at capital and replacement cost are (0.8) and (1), respectively. Used techno-economic viability analysis proved reduced *COE* about 3.52% with less weight for the system.

Table 3. Optimized Results of the Proposed Configuration with Weight Minimisation (Case 1 & 2)

| Capital Cost Multiplier by | Replace Cost Multiplier by | Case 1 | | | | Case 2 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | *COE* ($/kWh) | $W_{TOT.}$ (*ton*) | *fren* % | $Minf_2$ (p.u) | *COE* ($/kWh) | $W_{TOT.}$ (*ton*) | *fren* % | $Minf_2$ (p.u) |
| 0.6 | 0.6 | 0.166 | 121.08 | 91 | 0.42233 | 0.462 | 286.691 | 44 | 1 |
| 0.6 | 0.8 | 0.172 | 91.077 | 84 | 0.37683 | 0.467 | 241.691 | 28 | 1 |
| 0.6 | 1 | 0.176 | 91.077 | 84 | 0.37683 | 0.471 | 241.691 | 28 | 1 |
| 0.8 | 0.6 | 0.178 | 76.500 | 88 | 0.26683 | 0.475 | 286.691 | 34 | 1 |
| 0.8 | 0.8 | 0.182 | 91.077 | 84 | 0.38890 | 0.479 | 234.191 | 30 | 1 |
| 0.8 | 1 | 0.186 | 91.077 | 84 | 0.38890 | 0.483 | 234.191 | 30 | 1 |
| 1 | 0.6 | 0.187 | 121.08 | 89 | 0.42233 | 0.480 | 286.691 | 48 | 1 |
| 1 | 0.8 | 0.192 | 91.077 | 84 | 0.31768 | 0.488 | 286.691 | 48 | 1 |
| 1 | 1 | 0.197 | 91.077 | 84 | 0.40176 | 0.492 | 226.691 | 32 | 1 |

Table 4. Optimized Results of the Proposed Configuration with Weight Minimisation (Case 3 & 4)

| Capital Cost Multiplier by | Replace Cost Multiplier by | Case 3 | | | | Case 4 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | *COE* ($/kWh) | $W_{TOT.}$ (*ton*) | *fren* % | $Minf_2$ (p.u) | *COE* ($/kWh) | $W_{TOT.}$ (*ton*) | *fren* % | $Minf_2$(p.u) |
| 0.6 | 0.6 | 0.217 | 91.660 | 100 | 0.31971 | 0.174 | 91.379 | 93 | 0.31873 |
| 0.6 | 0.8 | 0.225 | 91.660 | 100 | 0.37924 | 0.178 | 76.379 | 91 | 0.31601 |
| 0.6 | 1 | 0.233 | 91.660 | 100 | 0.37924 | 0.183 | 76.379 | 91 | 0.31601 |
| 0.8 | 0.6 | 0.227 | 91.660 | 100 | 0.31971 | 0.183 | 106.38 | 95 | 0.37106 |
| 0.8 | 0.8 | 0.235 | 91.660 | 100 | 0.39138 | 0.188 | 76.379 | 91 | 0.32613 |
| 0.8 | 1 | 0.244 | 91.660 | 100 | 0.39138 | 0.192 | 68.879 | 89 | 0.26411 |
| 1 | 0.6 | 0.237 | 91.660 | 100 | 0.31971 | 0.190 | 91.379 | 93 | 0.31873 |
| 1 | 0.8 | 0.246 | 91.660 | 100 | 0.31971 | 0.195 | 76.379 | 91 | 0.26641 |
| 1 | 1 | 0.254 | 91.660 | 100 | 0.40433 | 0.199 | 68.879 | 89 | 0.30384 |

Table 5 shows the total CO2-emissions for cases (1 and 4) are 131.895 (ton/yr) and 87.934 (ton/yr), showing that case 4 results indicate a reasonable configuration. Regarding the less area of the system, we can see the renewable energy supplies the maximum part of the load demands, while the configuration of case 4 achieved 89% renewable energy and less cost of the fuel with less weight and area for RHES.

Table 5. Summary and comparison between cases (1 & 4)

| Items | Production of WT (MWh) | Production of PV (MWh) | Production of DG (MWh) | No. of WT | No. of PV panel | Size of Battery (1kWh LA) | Size of Power Conv. (kW) | $CO_2$ (*ton*/yr) | *FuelCost* ($) | $A_{(WT,PV)}$ $(m^2)$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Case 1 | 3752.846 | 0 | 185.54 | 75 | 0 | 1800 | 200 | 131.895 | 37565 | 76500 |
| Case 4 | 2501.897 | 302.88 | 123.97 | 50 | 200 | 1500 | 300 | 87.934 | 25045 | 55400 |

## 6. Conclusion

The analysis results revealed that the optimal location to build a hybrid system in the northern region is the Bayji location, in the middle region is the Abu Ghraib location and in the southern region is the AL Harithah location. Also, it is clear that the optimal location to build up RHES (off-grid) in Iraq is the AL Harithah location, which is regarded as an excellent location.Generally, it considered that the southern region is the optimal region in Iraq to create one or more hybrid systems because of the abundance of wind and solar radiation.

According to the analysis and selection of the most appropriate configuration and size for the RHES, we can see that the choice of case 4 (WT, PV, Dg) of Tables 3, 4 are the optimum regarding less weight and area. Also at less weight for the system, we can see reduced *COE* about 3.52% by using techno-economic viability-analysis. The Table 5 confirms that the case 4 configuration is much better than the case 1 configuration with reduced the area required for installation of the RHES about 28% with 33.3% for$CO_2$-emissions and 33.33% for fuel cost.

Finally, Reference [1, 3] proposed selected the AL Basrah and Mosul locations as the best site for the RHES construction in Iraq. After comparing the results of this paper with Reference [1, 3], it emerged that the AL Harithah location is better than the AL Basrah and Mosul locations.

## References


[1] Dihrab SS, Sopian K. Electricity generation of hybrid PV/wind systems in Iraq. *Renewable Energy*. 2010; 35(6): 1303-7.

[2] Iraq Wikipedia. Available online: https://en.wikipedia.org/wiki/Iraq (Accessed Jun. 2016).

[3] Al-Hafidh MS, Ibrahem MH, editors. *Hybrid power system for residential load*. 2013 International Conference on Electrical, Communication, Computer, Power, and Control Engineering (ICECCPCE), IEEE. 2013.

[4] Shahinzadeh H, Gharehpetian GB, Fathi SH, Nasr-Azadani SM. Optimal Planning of an Off-grid Electricity Generation with Renewable Energy Resources using the HOMER Software. *International Journal of Power Electronics and Drive Systems*. 2015; 6(1): 137.

[5] Diab F, Lan H, Zhang L, Ali S. An Environmentally-Friendly Tourist Village in Egypt Based on a Hybrid Renewable Energy System—Part One: What Is the Optimum City? *Energies*. 2015; 8(7): 6926-44.

[6] Alkababjie MF, Hamdon WH, editors. *Feasibility and environmental effects study of adding micro hydropower plant, converter and batteries to diesel generators using in electrification a remote Iraqi village*. 2012 First National Conference for Engineering Sciences (FNCES), IEEE. 2012.

[7] Dufo-López R, Cristóbal-Monreal IR, Yusta JM. Optimisation of PV-wind-diesel-battery stand-alone systems to minimise cost and maximise human development index and job creation. *Renewable Energy*. 2016; 94: 280-93.

[8] Nyo ZM. Evaluation of PV, Wind, Diesel Hybrid Energy Potential for GSM Tower in Myanmar. *International Journal of Electrical and Computer Engineering*. 2015; 5(6).

[9] Das HS, Yatim A, Tan CW, Lau KY. Proposition of a PV/tidal powered micro-hydro and diesel hybrid system: A southern Bangladesh focus. *Renewable and Sustainable Energy Reviews*. 2016; 53: 1137-48.

[10] Smaoui M, Abdelkafi A, Krichen L. Optimal sizing of stand-alone photovoltaic/wind/hydrogen hybrid system supplying a desalination unit. *Solar Energy*. 2015; 120: 263-76.

[11] Kaabeche A, Ibtiouen R. Techno-economic optimization of hybrid photovoltaic/wind/diesel/battery generation in a stand-alone power system. *Solar Energy*. 2014; 103: 171-82.

[12] Maleki A, Pourfayaz F. Sizing of stand-alone photovoltaic/wind/diesel system with battery and fuel cell storage devices by harmony search algorithm. *Journal of Energy Storage*. 2015; 2: 30-42.

[13] Merei G, Berger C, Sauer DU. Optimization of an off-grid hybrid PV–Wind–Diesel system with different battery technologies using genetic algorithm. *Solar Energy*. 2013; 97: 460-73.

[14] Nawawi Z, Aziz AS, Buntat Z, Sidik MA, Kareem HJ, Aziz MA, Abdulameer AZ, Jambak MI, Arief YZ. Performance Analysis of a VPV/FC Hybrid System for Generating Electricity in Iraq's Remote Areas. *TELKOMNIKA (Telecommunication Computing Electronics and Control)*. 2016; 14(2): 411-22.

[15] Shezan SA, Julai S, Kibria M, Ullah K, Saidur R, Chong W, et al. Performance analysis of an off-grid wind-PV (photovoltaic)-diesel-battery hybrid energy system feasible for remote areas. *Journal of Cleaner Production*. 2016; 125: 121-32.

[16] Belhamadia A, Mansor M, Younis M, editors. *Hybrid diesel/PV system sizing and cost estimation*. 3rd IET International Conference on Clean Energy and Technology (CEAT); IET. 2014,

[17] Abd MK, Cheng S, Sun H, editors. *Optimal DG placement and sizing for power loss reduction in a radial distribution system using MPGSA and sensitivity index method*. 2016 IEEE 11th Conference on Industrial Electronics and Applications (ICIEA), IEEE. 2016.

[18] Baghdadi F, Mohammedi K, Diaf S, Behar O. Feasibility study and energy conversion analysis of stand-alone hybrid renewable energy system. *Energy Conversion and Management*. 2015; 105: 471-9.

[19] Rezzouk H, Mellit A. Feasibility study and sensitivity analysis of a stand-alone photovoltaic–diesel–battery hybrid energy system in the north of Algeria. *Renewable and Sustainable Energy Reviews*. 2015; 43: 1134-50.

[20] Diab F, Lan H, Zhang L, Ali S. An environmentally friendly factory in Egypt based on hybrid photovoltaic/wind/diesel/battery system. *Journal of Cleaner Production*. 2016; 112: 3884-94.

[21] Maatallah T, Ghodhbane N, Nasrallah SB. Assessment viability for hybrid energy system (PV/wind/diesel) with storage in the northernmost city in Africa, Bizerte, Tunisia. *Renewable and Sustainable Energy Reviews*. 2016; 59: 1639-52.
[22] Zin AA, Moradi M, Tavalaei J, Naderipour A, Khavari AH, Moradi M. Techno-Economic Analysis of Stand-Alone Hybrid Energy System for the Electrification of Iran Drilling Oil Rigs. *TELKOMNIKA (Telecommunication, Computing, Electronics and Control)*. 2017; 15(2).
[23] Gheiratmand A, Effatnejad R, Hedayati M. Technical and economic evaluation of hybrid wind/PV/battery systems for Off-Grid areas using HOMER Software. *International Journal of Power Electronics and Drive Systems(IJPEDS)*. 2016; 7(1): 134.
[24] Mamaghani AH, Escandon SAA, Najafi B, Shirazi A, Rinaldi F. Techno-economic feasibility of photovoltaic, wind, diesel and hybrid electrification systems for off-grid rural electrification in Colombia. *Renewable Energy*. 2016; 97: 293-305.
[25] Index Mundi. Available online: http://www.indexmundi.com/g/r.aspx?v=81000 (Accessed on August 2017).
[26] Weather Base. Available online: http://www.weatherbase.com/weather/city.php3?c=IQ&name=Iraq (Accessed on August 2017).
[27] World Atlas. Available online: http://www.worldatls.com/webimage/countrys/asia/lgcolor/iqcolor.htm. (Accessed on August 2017).
[28] HOMER Pro Microgrid Analysis Tool x64 3.6.1. Available online: http://homerenergy.com/(Accessed on 18 September 2016).
[29] Sinha S, Chandel S. Review of software tools for hybrid renewable energy systems. *Renewable and Sustainable Energy Reviews*. 2014; 32: 192-205.