U.P.B. Sci. Bull., Series C, Vol. 79, Iss. 4, 2017 ISSN 2286-3540

EVALUATION OF AN INDUSTRIAL MICROGRID USING *HOMER* SOFTWARE

Andrei HORHOIANU[1], Mircea EREMIA[2]

The paper highlights the technical, economic and environmental aspects related to the development of a microgrid at an industrial oil field level. Microgrid simulation based on HOMER software has two main objectives. The first objective is to determine the feasibility of the microgrid. HOMER considers the microgrid being feasible if it is able to meet the electricity and heat demand, as well as other restrictions imposed by the user. The second goal is to estimate the life cycle cost of the microgrid, represented by the installation and lifetime operating costs. The availability of renewable energy resources strongly affects the behavior and financial aspects of microgrids based on such energies, because the amount of energy and generating duration are two functions strictly dependent upon the availability of primary energy resources.

Keywords: HOMER, microgrid, renewable energy, load demand

1. Introduction

The technical and economic analysis of a microgrid is a difficult process due to the number of design options and the uncertainty of key parameters, such as demand profiles of thermal or electrical loads or fuel prices. Moreover, renewables, by their intermittent nature and non-dispatchable seasonal production, add additional complexity. To overcome all challenges mentioned above, a series of software applications such as HOMER, RETScreen or DER-CAM can be used for the technical and economic analyzes. In this paper, we opted to use HOMER (Hybrid Optimization Model for Energy Resources) as it allows the user to carry out the simulation, optimization and sensitivity analysis of a microgrid model. To determine the microgrid's feasibility and life cycle cost, HOMER examines, in the simulation step, its hourly performances for the duration of one year. In the optimization phase, HOMER simulates a series of possible configurations for the microgrid, in order to determine the solution that satisfies all technical restrictions at a minimum life cycle cost. In the sensitivity analysis stage, HOMER performs a series of optimizations to smooth out uncertainties or changes in the assumptions considered. The optimization process determines the optimal values of design variables such as type, size and number of microgrid components, while the

[1] PhD student, Dept. of Electrical Power Systems, University POLITEHNICA of Bucharest, Romania, e-mail: andrei_horhoianu@yahoo.com
[2] Professor Emeritus, Dept. of Electrical Power Systems, University POLITEHNICA of Bucharest, Romania, e-mail: eremia1@yahoo.com

sensitivity analysis assesses the effects of uncertainties or changes on microgrid parameters such as average wind speed or the future fuel price. To limit the complexity of input data and allow for a fast and practical calculation, the simulation logic used by HOMER is less detailed than other simulation software such as DesignPro or Hybrid2 [1] used in technical and economic analysis of microgrids. On the other hand, HOMER is more detailed and advanced than software such as RETScreen, which does not allow time series simulations [2].

2. Microgrid characteristics

To highlight the technical, economic and environmental aspects of an industrial microgrid, we consider a microgrid developed on an existing oil field site. As shown in Fig. 1, it is assumed that the microgrid is interconnected to a public distribution network (20 kV) and it includes a series of production equipment and distributed energy sources for efficient and safe operation of the oil field resources.

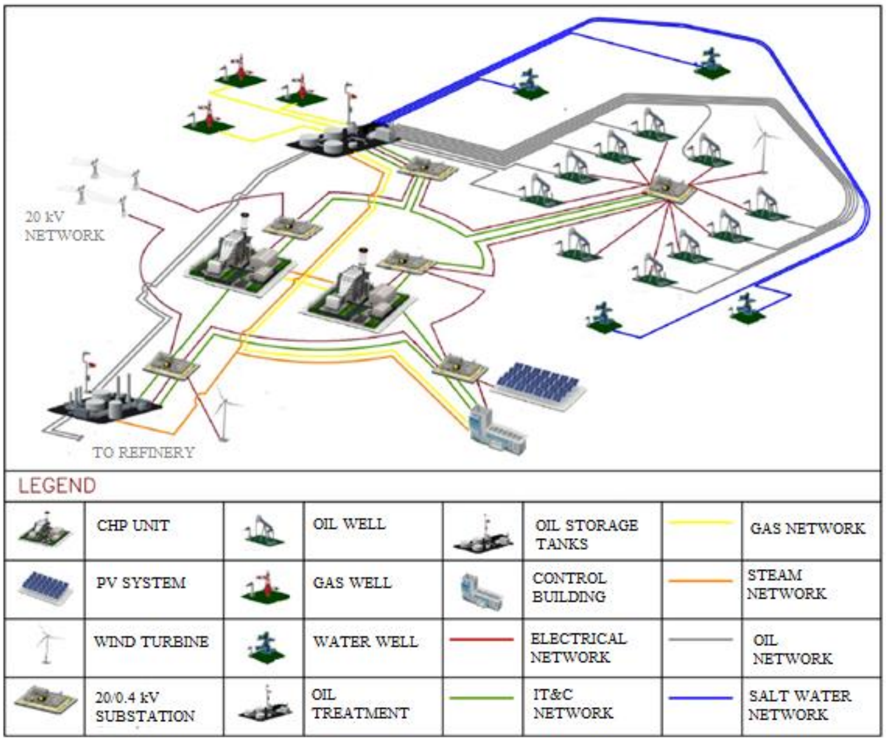


Fig. 1. The microgrid architecture analyzed using HOMER

In terms of energy resources, required for exploitation of the oil field, the microgrid includes two cogeneration units with gas turbines, one high capacity boiler, two wind turbines and a photovoltaic system with a battery string for ensuring power supply of critical equipment. The optimum capacity of each distributed generation unit is determined in the following sections using HOMER software.

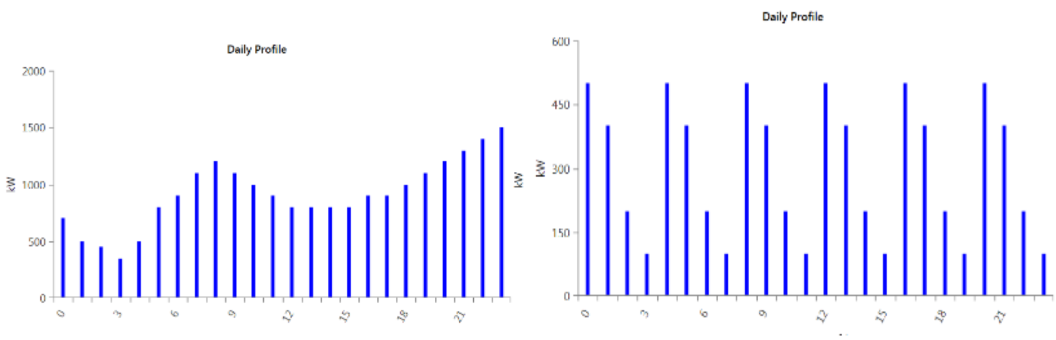
3. Microgrid components modeling

In HOMER simulation, the microgrid must include at least one electrical and/or one thermal power source, and one destination of the generated energy (e.g. electrical and/or thermal loads) or it must have the possibility of selling the generated energy to the network. In the following sections, we present the way microgrid components are modeled, using HOMER, as well as the technical and economic aspects related to their common operation.

A. Load modeling

HOMER defines the term load, as an electrical or thermal energy demand. The microgrid under review encompasses a number of electrical and thermal loads spread over a relatively small area (50 km^2) at all levels of oil production within the oil field. To simulate all these loads, HOMER requires the hourly values of electricity demand registered at point of common coupling (PCC) as well as the hourly values of thermal demand registered at the oil deposit and gathering and treatment station.

Considering typical demand profiles for electricity and thermal usage within an oil field from the North-East of Romania, we have set out in HOMER the daily profiles of the electrical (Fig. 2.a) and thermal loads (Fig. 2 b). These load profiles are dictated by the technological processes occurring at the oil field under review.



a) b)

Fig. 2. Daily *load profiles: (a) electrical (b) thermal*

Analyzing the load profiles highlighted in Fig. 2 above, we can conclude that at the point of common coupling, the total electrical demand of the microgrid has a daily average of 22.000 kWh/day and records two peak times (8:00 – 1200 kW and 23:00 – 1500 kW), while the thermal demand of the oil deposit and gathering and treatment station presents a daily average of 7200 kWh/day and a peak of 500 kWh/day every 3 hours. Based on the specified daily load profiles, HOMER determines the monthly and annually load profiles of the microgrid (Figs. 3 a and b).

a) b)

Fig. 3. Monthly and annual load profiles: (a) electrical (b) thermal

B. Energy resources modeling

In HOMER simulation, the term energy resource refers to any form of energy used by the microgrid to generate electrical power or heat. The energy resources available within the HOMER software include four forms of renewable energy (solar, wind hydro and biomass) as well as fossil fuel based systems. Renewable energy resources vary greatly depending on geographic location. For example: solar energy is strictly dependent on climate and latitude; wind power varies depending on weather fronts and landscaping; hydropower depends on landscaping topology and rain while the biomass resources depend on local biological productivity. Moreover, in any geographical areas, each renewable energy source presents seasonal or even hourly variations.

The availability of renewable energy resources strongly affects the behavior and financial aspects of a production system based on such energies because the amount of energy and production duration are two functions, strictly dependent upon the availability of primary energy resources. Therefore, the appropriate modeling of renewable energy is an important aspect of any program of technical and economic analysis.

For modeling the photovoltaic system, HOMER requires the geographical coordinates of the system. Therfore, it is considered that the analyzed microgrid is developed at an industrial oil field located in Moinesti, in the north-west of Romania. After selecting the geographic location, HOMER generates statistic data regarding the available solar energy in the selected area, using NASA database and an algorithm developed by Graham and Hollands [3]. The obtained statistics are presented in Fig. 4.

Month	Clearness Index	Daily Radiation (kWh/m²/day)
January	0.434	1.360
February	0.461	2.130
March	0.446	3.050
April	0.417	3.820
May	0.458	4.980
June	0.447	5.180
July	0.474	5.290
August	0.496	4.790
September	0.473	3.530
October	0.459	2.360
November	0.428	1.460
December	0.406	1.100

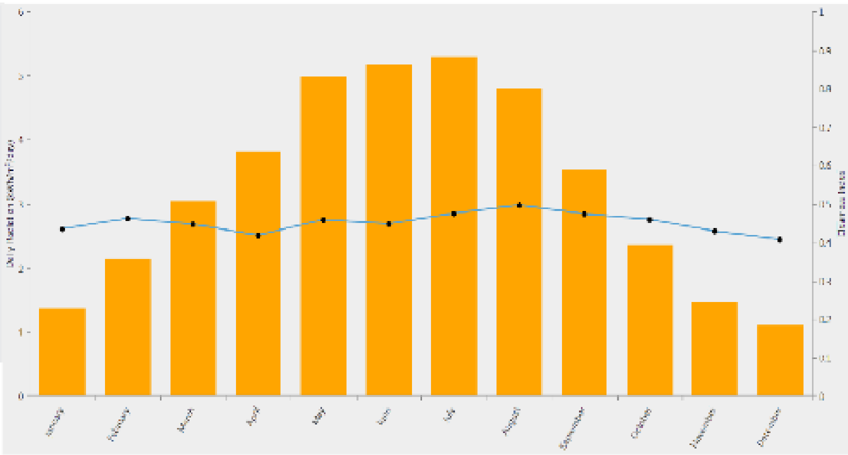


Fig. 4. Average values of solar radiation in Moinesti, Romania

As seen in Fig. 4, the horizontal solar radiation poses to the area under consideration, an annual average of 3.25 kWh/m^2/day and an average annual clarity index of 0.41. Clearness index, defined as a subunitary ratio between solar radiation at the ground level and the solar radiation at the atmosphere level, is a measure of atmosphere clarity. With regards to the photovoltaic system, this is modeled in HOMER as a device that produces electricity directly proportional to the incident solar radiation from its surface, and independently of temperature and voltage to which it is exposed.

HOMER calculates the energy produced by the photovoltaic system, using the following equation [6]:

$$P_{PV} = f_{PV} \cdot Y_{PV} \cdot \frac{I_T}{I_s} \quad (1)$$

where:

- P_{PV} – power generated by the photovoltaic system (kW)
- f_{PV} – correction factor of the nominal capacity
- Y_{PV} – nominal capacity of the photovoltaic system (kW)
- I_T – global solar radiation incident on the system surface (kW/m^2)

- I_s – standard amount of solar radiation used for specifying the nominal capacity of the PV system
  ($1\ kW/m^2$)

The nominal capacity of a photovoltaic system represents the power generated under standard test conditions. In HOMER, the power generated by the PV system is always specified as the nominal capacity. For every hour of the year, HOMER calculates the global solar radiation, incident on the surface of the PV system using HDKR model developed by Duffie and Beckmann [4]. This model takes into account: the amount of solar radiation global incidents in an open area; orientation of the PV system; geographic location, and time of the year and day.

The correction factor (f_{PV}) highlights the effects of dust, losses in cables, temperature and other factors that may cause deviations on the power generated by the photovoltaic system from the values recorded under standard test. HOMER does not consider the effect of temperature on the power generated by the photovoltaic system, but the correction factor can be reduced to take account of this aspect.

In reality, the power generated by the photovoltaic system depends strongly and nonlinearly on the voltage to which is exposed. The peak power (voltage level at which maximum power is generated) depends on solar radiation and temperature. If the photovoltaic system is connected directly to d.c. load or a battery system, then the voltage differs from the maximum point and system performance will suffer. To address this deficiency, a device called maximum power point tracker, is installed between the photovoltaic system and the other components so that the voltage to which the photovoltaic system is exposed, coincide with maximum value. HOMER considers that the simulated photovoltaic system has a maximum power point tracker by default. To carry out the economic calculations with HOMER, the user will have to specify the cost of initial investment ($), the replacement cost ($) and annual operating and maintenance costs ($/year). By default, the replacement cost is considered equal to the cost of initial investment.

To define the search space of the optimal solution, in terms of technical and economic aspects, we consider as standard values the following parameters:

- Initial investment cost for a 25 kW photovoltaic system - 75.000 $;
- Replacemnt cost for a 25 kW photovoltaic system - 75.000 $
- Annual operating and maintenance costs for a 25 kW photovoltaic system - 250 $/year
- Liftetime of 25 kW photovoltaic system - 25 years
- Correction factor - 80%

Considering these span values, the average value of solar energy in the selected geographic area, the load profiles and the features and restrictions on other elements of the microgrid (detailed in the following sections), HOMER generates a series of possible configurations to identify the optimal solution, characterized by a minimum net present cost. The characteristics of the photovoltaic system obtained for the optimal solution, are presented in Fig. 5.

Quantity	Value	Units
Rated Capacity	15,250.00	kW
Mean Output	2,067.50	kW
Mean Output	49,620.00	kWh/d
Capacity Factor	13.56	%
Total Production	18,111,406.00	kWh/yr

Quantity	Value	Units
Minimum Output	0.00	kW
Maximum Output	15,185	kW
PV Penetration	82.7	%
Hours of Operation	4,370	hrs/yr
Levelized Cost	0.187	$/kWh

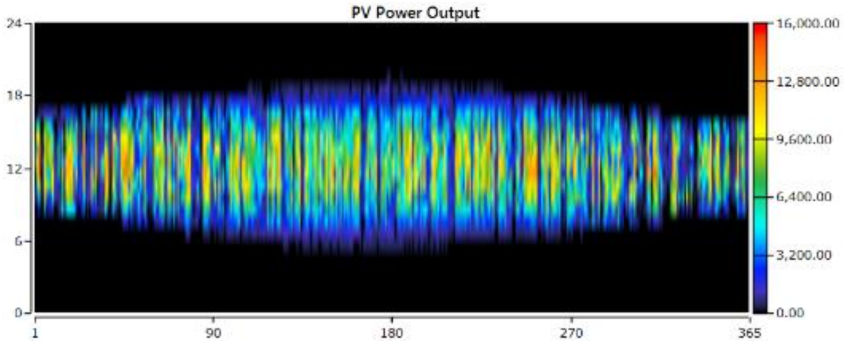


Fig. 5. Photovoltaic system characteristics obtained in the optimal solution

With regards to simulation of wind turbine systems in HOMER, the first step is to generate data on the wind energy, available in the selected geographical location. This data relates to the wind speeds encountered by the turbine during a year and can be specified by the user or automatically generated by HOMER using nASA database. In addition, HOMER generates four additional statistic parameters: Weibull form factor, autocorrelation factor, daily power pattern and peak hourly wind speed value. The characteristics of the wind speed, obtained by HOMER for the geographical location of our microgrid, are presented in Fig. 6 and 7.

Month	Average (m/s)
January	5.340
February	5.310
March	5.650
April	5.090
May	4.460
June	4.380
July	4.040
August	4.100
September	4.500
October	5.370
November	5.170
December	5.380

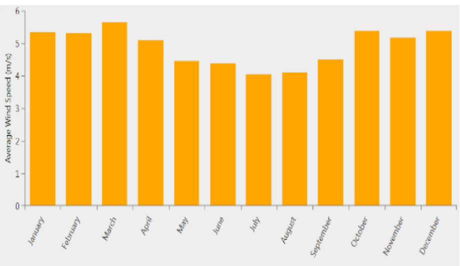


Fig. 6. Average wind speed values

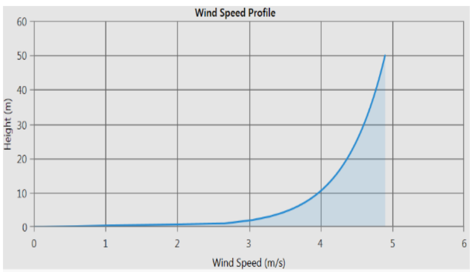


Fig. 7. Variation with altitude of wind speed

Analysing the above figures, we can observe that the wind speed has an average value of 4.9 m/s and a logarithmic profile with respect to the variation of the altitude. The wind speed additional parameters generated by HOMER are presented in Table 1.

Table 1

Wind speed parameters generated by HOMER

Parameter	Value
Weibull form factor	2
Autocorrelation factor	0.85
Daily load pattern	0.25
Peak hourly wind speed	15

The Weibull form factor is a measure of the wind speed distortion over the year. The autocorrelation factor highlights the dependence of wind speed at a certain hour on the wind speed recorded in the previous hour. The daily load pattern and peak hourly wind speed indicate the magnitude and phase of the daily wind speed model. The wind turbine is modeled in HOMER as a device that converts the kinetic wind energy into electricity after a power curve defined as a variation of the power generated by the wind velocity. To perform the simulations, HOMER considers a standard air density of $1.225\ kg/m^3$.

For each hour, HOMER calculates the power generated by the wind turbine, following a four-step process. Thus, in a first stage HOMER determines the average wind speed for the time considered on the basis of characteristic data previously generated for wind energy. In the second step, HOMER determines the average wind speed at the turbine nacelle using a function of speed variation with altitude (Fig. 9). In the third stage, based on the turbine power curve (Fig. 8) HOMER determines the power generated by the wind turbine considering the air standard density. In the final step, the power calculated in step 3 is multiplied with the ratio between the current air density and standard density.

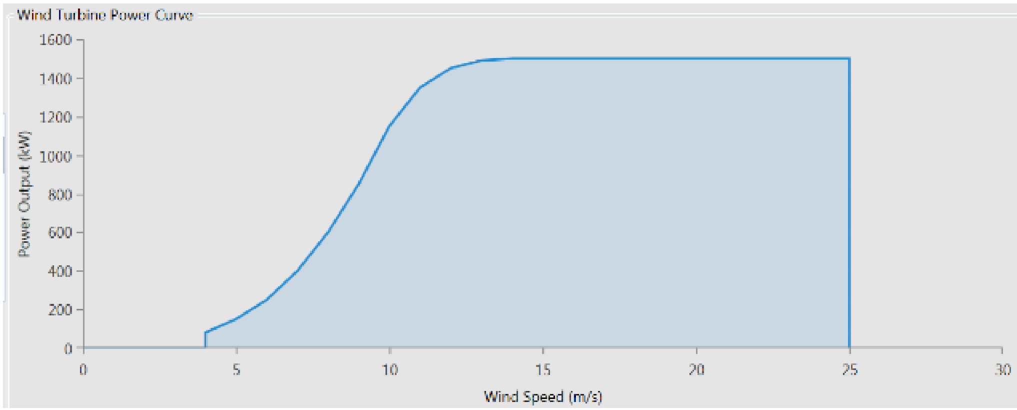


Fig. 8. Wind turbine power curve

To define the search space of the optimal solution, in terms of technical and economic aspects, we consider as standard values the following parameters:

- Initial investment cost for a 1500 kW wind turbine - 3 M $
- Replacement cost for a 1500 kW wind turbine - 3 M $
- Annual operating and maintenance costs - 0.03 M $/year
- Lifetime of the wind turbine - 20 years
- The nacelle height - 80 m

Considering these span values, the average value of wind energy in the selected geographic area, the load profiles and the features and restrictions on other elements of the microgrid (detailed in the following sections), HOMER generates a series of possible configurations to identify the optimal solution, characterized by a minimum net present cost. The characteristics of the wind turbine obtained for the optimal solution, are presented in Fig. 9.

Quantity	Value	Units
Total Rated Capacity	7,500.00	kW
Mean Output	275.85	kW
Capacity Factor	3.68	%
Total Production	2,416,450.00	kWh/yr

Quantity	Value	Units
Minimum Output	0.00	kW
Maximum Output	6,992.30	kW
Wind Penetration	11.03	%
Hours of Operation	2,459.00	hrs/yr
Levelized Cost	0.57	$/kWh

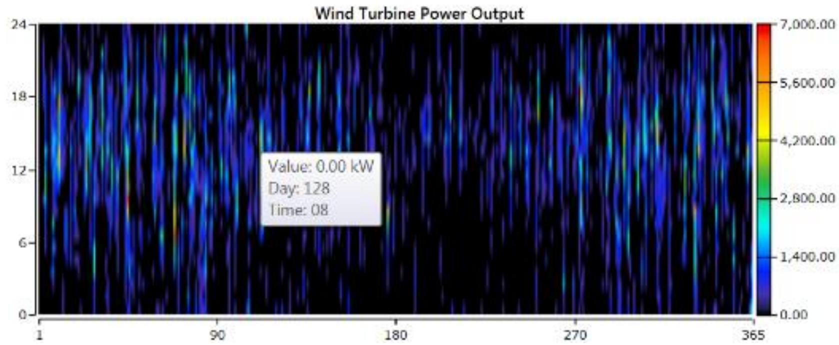


Fig. 9. Wind turbine characteristics obtained in the optimal solution

With regards to cogeneration plants, HOMER defines these as equipment used for generating electricity and heat from fossil fuels or biomass. The main physical parameters defined by HOMER user, refer to generated electricity (minimum and maximum), equipment lifetime in hours of operation, type of fuel used and consumption curve. To serve the electricity and heat demand of the oil field, we consider that the microgrid encloses two cogeneration plants with a capacity of 2000 kW each. The parameters specified in HOMER, are presented in Table 2.

Table 2

Parameters of cogeneration plants

Cogeneration plant	Parameter	Value
CG01, CG02	Capacity (kW)	2000
	Initial investment cost ($)	1.200.000
	Replacement cost ($)	1.200.000
	Annual operating and maintenance cost ($/year)	30.000
	Minimum loading (%)	10
	Lifetime (hours)	15.000.000
	Thermal energy recovery ratio (%)	40
	Minimum operating time (minutes)	120

As shown in Table 2, the two cogeneration plants have same technical characteristics and can operate alternately or simultaneously in order to satisfy the electricity and heat demand. We consider that the natural gas extracted in the oil field represents the fuel used by the cogeneration plants following the consumption curve presented in Fig. 10.

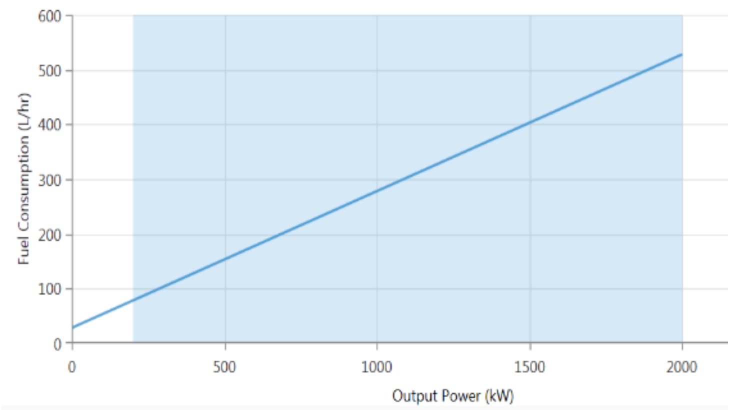


Fig. 10. Fuel consumption curves of cogeneration plants

The properties of the gas produced within the oil field and used within the cogeneration plants, are presented in Table 3.

Table 3

Fuel parameters

Parameter	Value
Higher heating value (MJ/kg)	43.2
Density (kg/m^3)	820
Carbon content (%)	88
Sulf content (%)	0.33

HOMER defines the fuel consumption curve using the following equation [6]:

$$F = F_0 Y_{gen} + F_1 P_{gen} \quad (2)$$

where:

- F_0 – consumption curve interception coefficient, in l/hr/kW
- F_1 – consumption curve slope, in l/hr/kW
- Y_{gen} – nominal capacity of the cogeneration unit, in kW
- P_{gen} – electrical energy produced by the cogeneration unit, in kW

The emissions of pollutants are also taken into consideration in the microgrid simulation. The emissions values considered for each of the two cogeneration plants, are presented in Table 4.

Table 4

Pollutants emissions values

Pollutant	**Value**
Carbon monoxide (g/l)	6.5
Incompletely burned hydrocarbons (g/l)	0.72
Solide particles (g/l)	0.49
Sulfur based compounds (g/l)	2.2
Nitrogen oxides (g/l)	58

Based the on economic parameters defined in Table 2, HOMER calculates the fixed and marginal cost of generating energy. These values are then used in the simulation phase to determine the optimal economic and technical solution.

HOMER calculates the fixed cost of producing energy using the following equation [6]:

$$c_{gen,fix} = c_{om,gen} + \frac{C_{rep,gen}}{R_{gen}} + F_0 Y_{gen} \cdot c_{fuel,eff} \tag{3}$$

where:

- $c_{om,gen}$ –operating and maintenance costs, in \$/hour
- $C_{rep,gen}$ – replacement cost, in \$
- R_{gen} – lifetime, in hrs
- F_0 – consumption curve interception coefficient, in L/hr/kW
- Y_{gen} – nomial capacity of the cogeneration unit, in kW
- $c_{fuel,eff}$ –fuel cost (including penalties due to pulluants), in \$/l

HOMER calculates the marginal cost of producing energy using the equation [6]:

$$c_{gen,mar} = F_1 \cdot c_{fuel,eff} \tag{4}$$

where:

- F_1 – consumption curve slope, in l/hr/kW
- $c_{fuel,eff}$ – fuel cost (including penalties due to pulluants), in \$/l

Taking into account all the above, the HOMER generates a series of possible configurations to identify the optimal solution, characterized by a net present cost. The characteristics of the cogeneration plants for the optimal solution, are presented in Fig. 11.

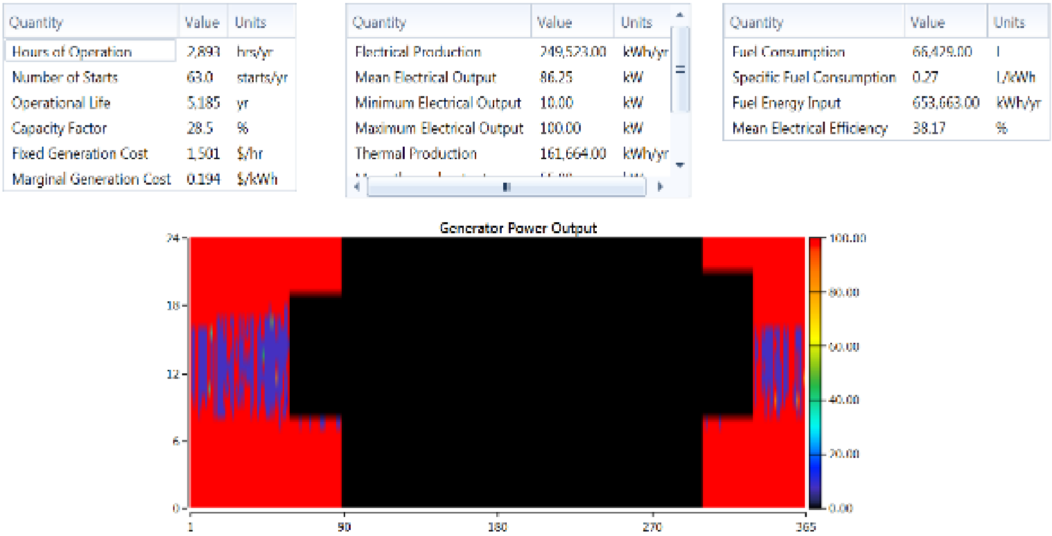


Fig. 11. Cogeneration plants characteristics obtained in the optimal solution

The battery system enclosed within the microgrid is modeled in HOMER as a device capable of storing a certain amount of energy at a reasonable efficiency with a number of restrictions in terms of duration of loading, discharging and lifetime. It is assumed that the properties of the battery system, remain constant throughout its lifetime and are not affected by external factors such as temperature.

The main physical parameters of the battery system, specified by HOMER user are: rated voltage, rated power, lifetime, initial charge status, minimum charging status and efficiency. The values of these parameters for the battery system enclosed within the microgrid are summarized in Table 5.

Table 5

Battery system parameters

Parameter	Value
Nominal voltage (V)	48
Nominal power (kWh)	70
Initial charging status (%)	100
Minimum charging status (%)	40
Efficiency (%)	64
Lifetime (years)	20

In order to calculate the maximum degree of loading or unloading of the battery system, HOMER considers the battery kinetic model [5], wherein the battery is regarded as a system of two containers, as shown in Fig. 12.

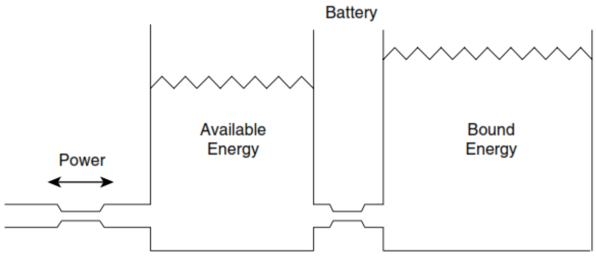


Fig. 12. Battery kinetic model

According to the kinetic model, some of the energy stored in the battery is immediately available for loading / unloading and the rest depends on the nature of chemical bonds in the battery energy. The conversion rate of this type of energy depends on the "height" of the two tanks. In this model, the battery is described using the following parameters:

- maximum capacity - the total size of the two tanks
- capacity rate - the ratio between the available energy the bound energy
- constant conversion rate - the dimension of pipeline between the two tanks

The battery kinetic model explains the typical capacity curve (Fig. 13) for a battery system modeled in HOMER. Therefore, for high discharge rates, the tank is draining quickly the available energy and only a small fraction of the bound energy can be transferred to the reservoir of available energy, before it is discharged. At this point of time, the battery can no longer cope with the demand and behave like a completely empty tank.

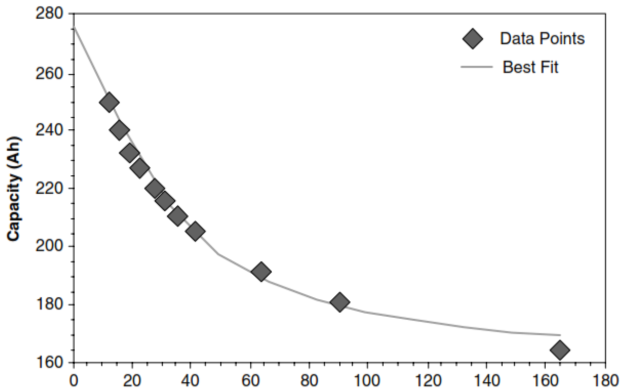


Fig. 13. Typical capacity curve for a US-250 battery (www.usbattery.com)

Simulating the battery as a system of two reservoirs, allows emphasizing the following two specific aspects:

- The battery cannot charge/discharge fast; a full charge requires an infinite amount of time for a given load current, which tends to zero.
- The battery's ability to charge/discharge, depends not only on the charging status but also in the history of recent charge/discharge cycle.

Therefore, a charged battery to 80% state of charge, will face higher discharge rates, compared to a battery with a quick discharge to 80% because it has a higher level in the reservoir of available energy. HOMER allows modeling of both aspects outlined above, using kinetic model.

To perform the economic calculation using HOMER, the user has to specify the cost of the battery system, the replacement cost and the annual cost of operation and maintenance. The costs considered for the battery system enclosed within our microgrid are presented in Table 6.

Table 6

Specific costs for a 70 kWh battery system

Cost	Value
Initial investment cost ($)	3.500
Replacement cost ($)	3.500
Annual maintenance and operation cost ($/year)	20

Due to the fact that the battery system is modeled as a dispatchable energy source, HOMER calculates both fixed marginal costs, in order to make the necessary comparisons with the other dispatchable systems and to determine the optimal solution. Unlike cogeneration systems, the battery system is available immediately for electricity production and therefore it is considered that the fixed cost of energy is zero. The marginal cost consists of the deterioration cost of the battery system (cost / kWh of energy required to charge the battery system) and the average cost of energy stored in the battery.

The deterioration cost of the battery system, is determined using equation [6]:

$$c_{bw} = \frac{C_{rep,batt}}{N_{batt} Q_{lifetime} \sqrt{\eta_{rt}}} \quad (5)$$

where:

- $C_{rep,batt}$ – replacement cost of the battery system, in $
- N_{batt} – number of batteries enclosed in the system
- $Q_{lifetime}$ – battery lifetime, in kWh
- η_{rt}– efficiency of the battery system

The characteristics of the battery system obtained in the optimal solution, are presented in Fig. 14.

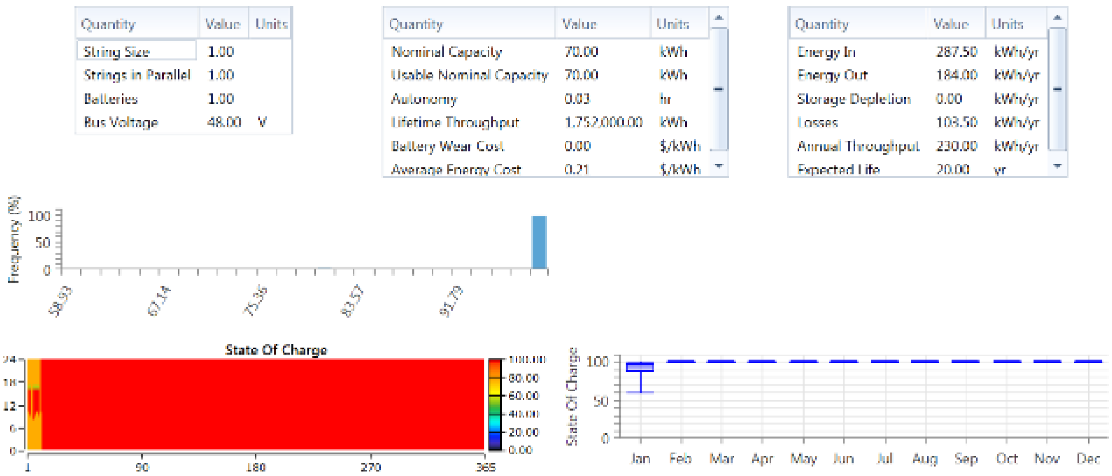


Fig. 14. Battery system characteristics obtained in the optimal solution

4. Simulation economic results

In the following paragraphs we present the economic results for the optimal microgrid architecture obtained using HOMER. The optimal solution is characterized by a minimum lifecycle cost and includes the following components: a photovoltaic system, two wind generators, two cogeneration units and a battery system equipped with a reversible AC/DC converter. The life cycle cost elements of the microgrid are graphically summarized in Table 7.

Table 7

Life cycle cost elements

System/Equipment	Investment Cost [MM $]	Replacement Cost [MM $]	O&M Cost [MM $]	Fuel Cost [MM $]	Residual Value [MM $]	Total [MM $]
Photovoltaic System PV01	45	0	2.1	0	0	47.1
Wind Turbine GE01	3	1	0.5	0	-0.6	3.9
Wind Turbine GE02	3	1	0.5	0	-0.6	3.9
Cogeneration Unit CG01	0.06	0	61	2.5	-0.01	63.55
Cogeneration Unit CG02	0.06	0.01	61	2.5	-0.01	63.55
Distribution Network	0	0	6	0	0	6
Battery System	0.03	0.01	0.01	0	0	0.05
AC/DC Converter	0.01	0.01	0	0	0	0.02
Contingency	0	0	5	0	0	5
Microgrid	**52.24**	**2.03**	**136.11**	**5**	**1.22**	**193.07**

The life cycle cost of the equipment / system represents the present value of all costs of installing and operating it for the entire life of the project (considered 25) minus the present value of all revenue generated by the equipment / system throughout the life of the project. HOMER calculates the life cycle cost of each microgrid component and also for the whole microgrid. The discount rate used is 6%. To determine the life cycle cost, HOMER generates a cash flow chart (Fig. 57) in which all the cash flows are costs and appear as negative numbers, excluding the residual value, which appears at the end of the project.

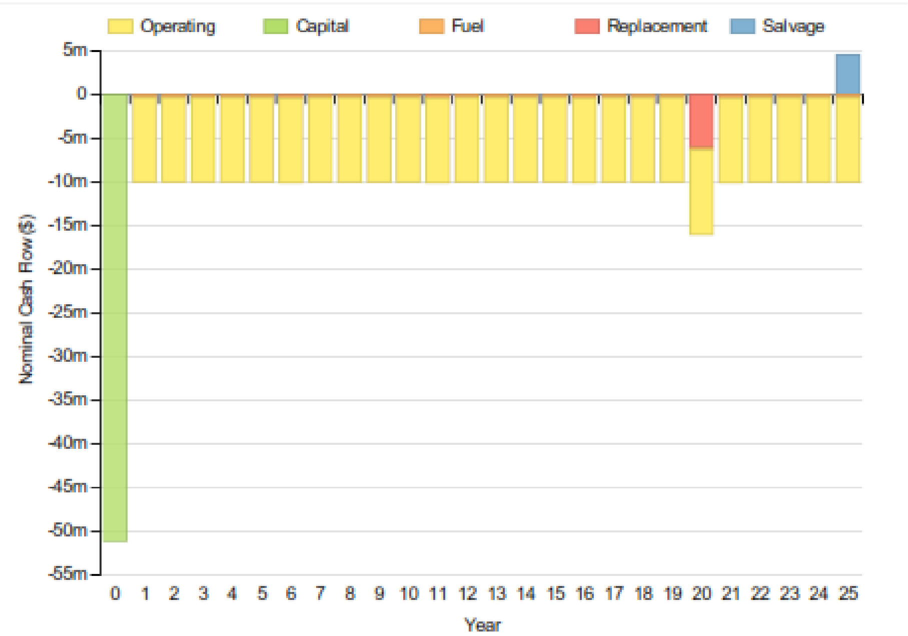


Fig. 15. Microgrid cash flow

The residual value of the equipment / energy system is defined as the remaining value of the equipment at the end of the project. HOMER considers a linear depreciation of equipment, which means that residual value is directly proportional to the remaining life. It is also assumed that the residual value depends on the replacement cost and not on the cost of the initial investment.

HOMER calculates the residual value using the following equations [6]:

$$S = C_{rep} \cdot \frac{R_{rem}}{R_{comp}} \tag{6}$$

where, $R_{rem} = R_{comp} - (R_{proj} - R_{rep})$ (7)

and, $R_{rep} = R_{comp} \cdot INT(\frac{R_{proj}}{R_{comp}})$ (8)

The terms of the above equations, have the following meaning:

- S – residual value [$]
- C_{rep} – replacement cost [$]
- R_{comp} – equipment lifetime [years]
- R_{proj} – project life [years]
- $INT()$ – integer function

5. Pollutant emissions evaluation

The main systems enclosed within the microgrid that generate emissions are the two cogeneration units (CG01 and CG02). The quantities and types of emissions determined by HOMER for these systems, are presented in Table 8.

Table 8

Microgrid pollutant emissions

Pollutant	Quantity [kg/year]
Carbon dioxide	3559660
Carbon monoxide	4692
Unburned hydrocarbons	520
Particulate matter	354
Sulf dioxide	11009
Nitrogen oxides	45382

HOMER considers by default, a penalty cost of $10 / tonne for each type of pollutant specified in Table 8. This cost penalty is reflected in the composition of the costs of operation and maintenance (O & M) specified in Table 7.

6. Conclusion

HOMER is a software application that simulates all possible microgrid configurations for which the user wants to analyze the technical and economic aspects. Simulated systems can be sorted and filtered into the optimization phase depending on criteria set by the user in order to determine the optimal solution. Although fundamentally HOMER is an economic optimization software, it can be used to minimize fuel consumption or sensitivities analysis such as wind speed, sunlight, fuel cost, etc.

Implementation of a microgrid at an oil field is a difficult process due to the number of design options and the uncertainty of key parameters, such as thermal or electrical load profiles and fuel prices. Moreover, renewables by their intermittent nature and nondispatchable seasonal production, add additional complexity.

The particularity of the processes undertaken at an oil field impose the entrainment of dispatchable power sources to ensure the flexibility required to satisfy the electricity and heat demand. However, the dispatchable power sources are generally based on fossil fuel and have a negative impact on the microgrid life cycle cost. In addition, penalties related to air pollution significantly increase the opreating and maintenance costs.

R E F E R E N C E S

[1] *J. F. Manwell and J. G. McGowan*, "A combined probabilistic/time series model for wind diesel systems simulation", Solar Energy, Vol. 53, pp. 481–490, 2014

[2] RETScreen International http://www.retscreen.net

[3] *V. A. Graham and K. G. T. Hollands*, "A method to generate synthetic hourly solar radiation globally", Solar Energy, Vol. 44, No. 6, pp. 333–341, 2012

[4] *J. A. Duffie and W. A. Beckman*, "Solar Engineering of Thermal Processes" 2nd ed., Wiley, New York, 2013

[5] *J. F. Manwell and J. G. McGowan,* "Lead acid battery storage model for hybrid energy systems", Solar Energy, Vol. 50, pp. 399–405, 2012.

[6] "Homer Energy", Homer Help Manual, 2015

[7] *M. A. M. Ramli, A. Hiendro, S. Twaha,* "Economic analysis of PV/diesel hybrid system with flywheel energy storage", Renew. Energy, vol. 78, pp. 398-405, 2015.

[8] *B. Tudu, K. K. Mandal, N. Chakraborty*, "Optimal design and performance evaluation of a grid independent hybrid micro hydro-solar-wind-fuel cell energy system using meta-heuristic techniques", 2014 1st International Conference on Non-Conventional Energy (ICONCE 2014), Jan. 2014.

[9] *M. J. Khan, M. T. Iqbal,* "Pre-feasibility study of stand-alone hybrid energy systems for applications in Newfoundland", Renewable Energy, vol. 30, no. 6, pp. 835-854, May 2015.