SIMULATION OF THE SYSTEMS WITH RENEWABLE ENERGY SOURCES USING HOMER SOFTWARE

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Abstract - This paper simulates by using the Homer software, a distributed energy system with capacity below 1 MW. Among the renewable energy sources are used wind and solar energy. For photovoltaic panels, we are considering two situations: fixed panels, oriented at 45° and panels with tracking system with two axis. Simulation results contain information regarding operation hours of the system throughout the year, energy produced from the renewable energy sources, energy consumption for the load, and excess of electrical energy. The Homer software also allows an economic analysis of these systems.

Keywords: Solar energy, wind energy, the Homer software

1. INTRODUCTION

The use of renewable energy sources either as distributed generators in public AC networks or as isolated generating units supplying is one of the new trends in power-electronic technology. Renewable energy generators equipped with electronic converters can be attractive for several reasons, such as environmental benefits, economic convenience, social development. The main environmental benefit obtained by using renewable sources instead of traditional sources, is the reduction in carbon emission.

Many countries have adopted policies to promote renewable sources in order to respect the limits on carbon emission imposed by international agreements.

Use of distributed renewable generation units contributes to decentralise the electrical energy production, with a positive impact on the development of remote areas. The exploitation of local renewable sources supports local economies and lightens the energy supply dependency from fuels availability and prices fluctuations.

The integration in the electric grid of distributed power generation systems, located close to the loads, reduces the need to transfer energy over long distances through the electric grid. In this way several benefits are achieved, such as the reduction of bottle-neck points created by overcharged lines, the increase of global efficiency and the limitation of thermal stress on grid conductors.

Renewable distributed generation units, if properly controlled and designed can improve the power flow management on the grid and reduce the probability of grid faults, so increasing the power quality of the energy supply. It's important to evaluate also the possible drawbacks of the increasing number of renewable energy sources on the power-supply stability and quality, both in grid connected and stand-alone configurations, in order to prevent possible problems with a proper design and management of this generation units [1].

Table 1, [2] compares the advantages and disadvantages of various DG technologies.

From Table 2, it can be seen that the fuel cell, wind turbines, photovoltaic modules and micro hydropower plants are free general directions of emissions and requires no fuel and they are environmental friendly. DGs most appropriate taking into account environmental concerns, fuel costs, maintenance costs and power output are identified as wind, SPV, biomass, small hydro, etc.

Table 1. Comparison between main DG technologies

Sl. No.	DG Technology	Advantages	Disadvantages
1	Fuel Cell	High efficiency Low noise Nearly zero emission Fast load response	Pure hydrogen need High cost Low durability Fuel required processing
2	Micro Turbine	Low noise Low emission Light weight Small size	High cost Limited to low temperature Relatively low efficiency
3	Wind Turbine	Low production cost Low energy loss Environmental friendly Save land use No fuel demand	Affected by wind speed Variable power output Noise High investment cost Harm birds
4	Solar PV	Low maintenance Environmental friendly No fuel demand	High investment cost Affected by solar radiation
5	CHP	High efficiency Low emission Save energy loss Integration various fuels	Increased investment cost Need reasonable plan Decrease flexibility Reclaim complex technology
6	Gas turbine	High reliability Low emission	High pressure gas need Low efficiency at low load
7	Reciprocating engine	Fast start- up Low investment	Relatively higher emission High maintenance
8	Small hydro	Free and renewable source of energy No impact on river eco-system Short installation time Environmental friendly	Power output depends on availability of water Affected by flood They can be suited where potential site exists Can't meet required load demand Continuous maintenance is required
9	Biomass plant	Uses renewable source Reduces dependency on fossil fuel Reduces green house gas emissions	Expensive Causes pollution Limited source

This article analyzes the situation when consumers own the capacity to produce electric energy from renewable energy sources with total installed power consumption below 1 MW.

Consumers must use electricity mainly for own consumption. Surplus electricity is taken by the supplier at a price regulated by ANRE (National Association of Energy Regulators) [3].

2. HOMER SOFTWARE

HOMER (The Hybrid Optimization Model for Electricity Renewables) [4] is primarily an optimisation software package which simulates varied configurations renewable energy sources (RES) and scales them on the basis of NPC (Net present cost). HOMER firstly assesses the technical feasibility of the RES system (i.e. whether the system can adequately serve the electrical and thermal loads and any other constraints imposed by the user). Secondly, it estimates the NPC of the system, which is the total cost of installing and operating the system over its lifetime.

For each combination, Homer calculates these economical aspects:

- Total Net Present Cost (NPC) includes the costs of initial construction, component replacements, maintenance, fuel, plus the cost of buying power from grid and miscellaneous costs and hence is used to represent the life cycle cost of a system, and determined by the following equation:

$$C_{NPC} = \frac{C_{ann.tot}}{CRF(i, R_{proj})} \qquad (1)$$

where,

$C_{ann,tot}$ - the total annualized cost;

i - the annual real interest rate;

R_{proj} - the project lifetime;

CRF - is the capital recovery factor which represent the % of initial capital cost to recover the cost of capital investment.

- To determine the net present cost, the *CRF* is alculated by the equation:

$$CRF(i,N) = \frac{i \cdot (1+i)^N}{(1+i)^N - 1} \qquad (2)$$

where,

N - the number of years.

- The average cost per kWh of electricity produced by system is known as levelized cost of energy or Cost of Energy (COE) and is determined by following equation:

$$COE = \frac{C_{ann,tot}}{E_{prim,AC} + E_{grid,sales}} \qquad (3)$$

where,

$C_{ann,tot}$ - the total annualized cost, [$/year];

$E_{prim,AC}$ - primary load served [kWh/yr];

$E_{grid,sale}$ - the total grid sales, [kWh/year].

HOMER uses the following equation to calculate the output of the PV array:

$$P_{PV} = Y_{PV} \cdot f_{PV} \cdot \left(\frac{\bar{G}_T}{\bar{G}_{T,STC}} \right) \left[1 + \alpha_p \left(T_c - T_{c,STC} \right) \right] (3)$$

where,

Y_{PV} - the rated capacity of the PV array, meaning its power output under standard test conditions, [kW];

f_{PV} - the PV derating factor, [%];

$\bar{G}_T$ - the solar radiation incident on the PV array in the current time step, [kW/m^2];

$\bar{G}_{T,STC}$ - the incident radiation at standard test conditions, [1 kW/m^2];

α_p - the temperature coefficient of power, [%/°C];

T_c - the PV cell temperature in the current time step, [°C]

$T_{c,STC}$ - the PV cell temperature under standard test conditions, [25 °C]

Photovoltaic panels are typically mounted at a fixed orientation. They can, however, be made to "track" the sun in order to maximize the incident solar radiation. Tracking systems are classified according to the number of axes of rotation and the frequency with which the adjustments are made.

HOMER can consider the following tracking systems:

- **No Tracking**: Panels are mounted at a fixed slope and azimuth. This is the simplest and most common case.
- **Horizontal Axis, monthly adjustment**: Rotation is about a horizontal east-west axis. The slope is adjusted on the first day of every month so that the sun's rays are perpendicular to the surface at noon of that day.
- **Horizontal Axis, weekly adjustment**: Rotation is about a horizontal east-west axis. The slope is adjusted on the first day of every week so that the sun's rays are perpendicular to the surface at noon of that day.
- **Horizontal Axis, daily adjustment**: Rotation is about a horizontal east-west axis. The slope is adjusted each day so that the sun's rays are perpendicular to the surface at noon.
- **Horizontal Axis, continuous adjustment**: Rotation is about a horizontal east-west axis. The slope is adjusted continually in order to minimize the angle on incidence.
- **Vertical Axis, continuous adjustment**: Rotation is about a vertical axis. The slope is fixed, but the azimuth is continually adjusted to minimize the angle of incidence.
- **Two Axis**: The panels are rotated about both horizontal and vertical axes so that the sun's rays are always perpendicular to the surface. This type of tracking system maximizes the power production of the PV panels, but it is the most expensive.

3. SIMULATION OF A DISTRIBUTED GENERATION SYSTEM

3.1 Main operation data and constraints of the hybrid power system.

The system analyzed consists of wind turbines and photovoltaic panels.

The lifetime of the proposed system is 25 years. The annual real interest rate is 10%.

Simulation of hybrid system with renewable energy sources (Fig. 1) is achieved with the help of Homer software.

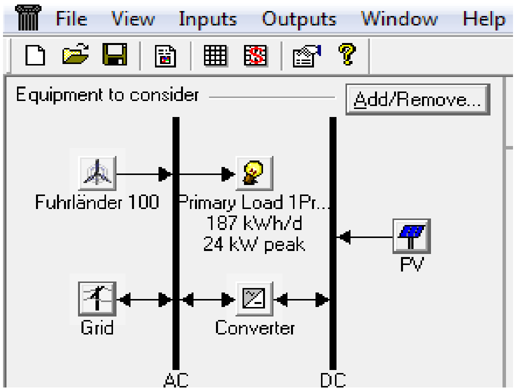


Fig. 1. Hybrid Renewable Energy System

A typical system of consumers (Fig. 2), have been taken into account in the analysis. This figure shows the variation for a day of each month. The data from this figure are introduced in the Homer software to obtain the load variation for each day of each month of the year. Energy consumption is not the same every day of every month. Homer software allows us to vary consumption from day to day and from hour to hour. So based on variation from Figure 2 and applying consumption variations from one day to another with 20% and one hour to another with 15% it is obtained the data in Figure 3, where the peak value (used for simulations in this article) is over 20 kW.

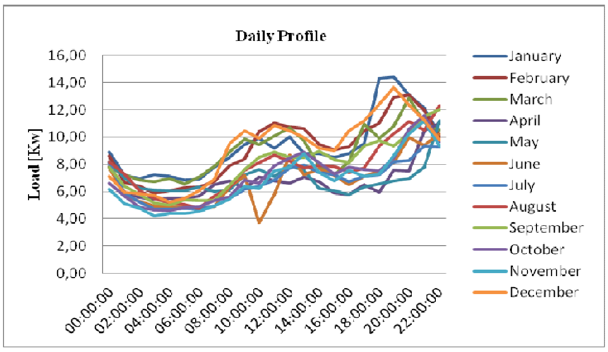
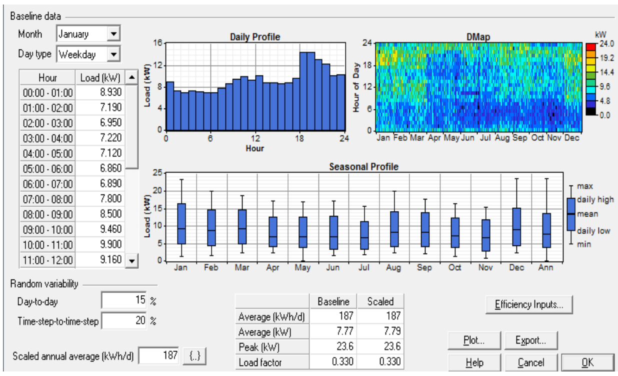


Fig. 2. Power demand for consumer group



Baseline data

Month: January

Day type: Weekday

Hour	Load (kW)
00:00 - 01:00	8.930
01:00 - 02:00	7.190
02:00 - 03:00	6.950
03:00 - 04:00	7.220
04:00 - 05:00	7.120
05:00 - 06:00	6.860
06:00 - 07:00	6.890
07:00 - 08:00	7.800
08:00 - 09:00	8.500
09:00 - 10:00	9.460
10:00 - 11:00	9.900
11:00 - 12:00	9.160

Random variability

Day-to-day: 15 %

Time-step-to-time-step: 20 %

Scaled annual average (kWh/d): 187 {..}

	Baseline	Scaled
Average (kWh/d)	187	187
Average (kW)	7.77	7.79
Peak (kW)	23.6	23.6
Load factor	0.330	0.330

Fig. 3. Primary load inputs

It appears that the group of consumers (Fig. 3), consumes around 187 kWh/d with a peak demand of about 24 kW.

Information on meteorological data required to implement in the HOMER software are obtained using RETScreen software [5] which allows the provision of the solar radiation, wind speed at 10 m height, latitude, longitude and temperature.

These data are presented in Table 2.

Table 2. Monthly average wind power, solar radiation and temperature for Craiova

Month	Wind Speed [m/s]	Daily irradiation [kWh/m^2/d]	Clearness index	Temperature [^{o}C]
January	2.600	1.500	0.423	-1.0
February	3.300	2.540	0.510	0.9
March	3.800	3.620	0.511	5.8
April	4.100	4.730	0.509	11.7
May	3.400	5.820	0.533	17.1
June	3.000	6.350	0.548	20.6
July	2.800	6.290	0.560	22.9
August	2.800	5.460	0.553	25.5
September	2.900	4.000	0.511	17.9
October	2.800	2.790	0.499	11.8
November	2.700	1.680	0.435	4.7
December	2.500	1.240	0.397	0.0
Anual average	3.055	3.842	0.512	11.6

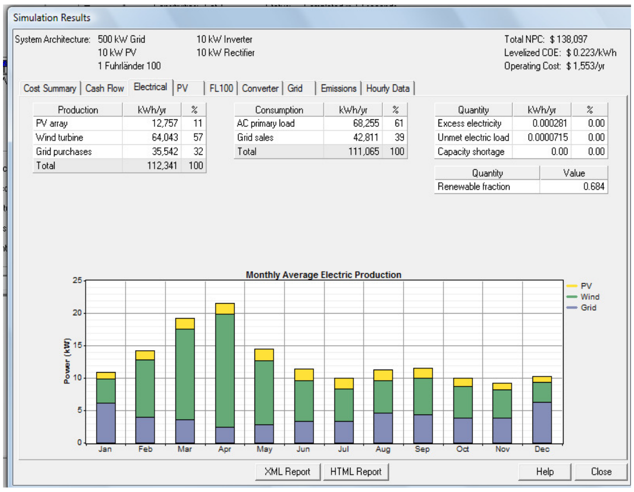
There are analyzed two cases for photovoltaic panels:
Case 1: Fixed panels;
Case 2: Oriented panels after two axis.

3.2 Simulation results for considered hybrid system

From figures 4 and 5 it is observed that the share of renewable energy is 68.4% in the first case and 70.5 in the second case.

In both cases selling price of surplus energy is 0.2$/kWh.

The cost of energy (COE) for case 1 is 0.223$/kWh and 0.220$/kWh for case 2.



System Architecture: 500 kW Grid, 10 kW PV, 1 Fuhrländer 100, 10 kW Inverter, 10 kW Rectifier

Total NPC: $ 138,097
Levelized COE: $ 0.223/kWh
Operating Cost: $ 1,553/yr

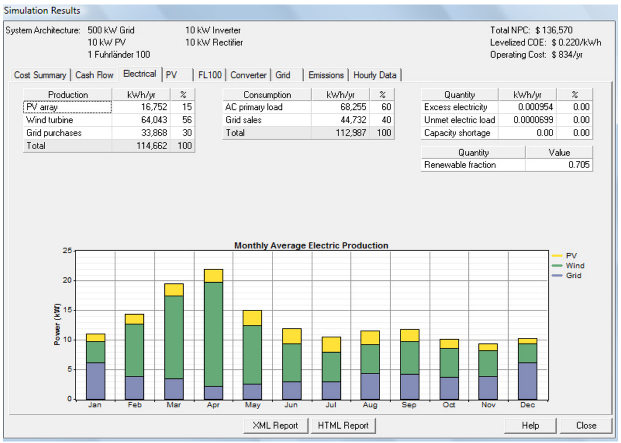
Production	kWh/yr	%
PV array	12,757	11
Wind turbine	64,043	57
Grid purchases	35,542	32
Total	112,341	100

Consumption	kWh/yr	%
AC primary load	68,255	61
Grid sales	42,811	39
Total	111,065	100

Quantity	kWh/yr	%
Excess electricity	0.000281	0.00
Unmet electric load	0.0000715	0.00
Capacity shortage	0.00	0.00

Quantity	Value
Renewable fraction	0.684

Fig. 4. Monthly average production of electric energy Case 1



System Architecture: 500 kW Grid
10 kW PV
1 Fuhrländer 100
10 kW Inverter
10 kW Rectifier

Total NPC: $ 136,570
Levelized COE: $ 0.220/kWh
Operating Cost: $ 834/yr

Production	kWh/yr	%
PV array	16,752	15
Wind turbine	64,043	56
Grid purchases	33,868	30
Total	114,662	100

Consumption	kWh/yr	%
AC primary load	68,255	60
Grid sales	44,732	40
Total	112,987	100

Quantity	kWh/yr	%
Excess electricity	0.000954	0.00
Unmet electric load	0.0000699	0.00
Capacity shortage	0.00	0.00

Quantity	Value
Renewable fraction	0.705

Fig. 5. Monthly average production of electric energy - Case 2

The table 3 and 4 shows the exchange energy for the two variants considered.

The fourth column of Tables 3 and 4 represents net purchases grid which is defined as grid purchases minus grid sales.

HOMER calculates the total annual energy charge (shown in the last column of Tables III and IV) using the following equation:

$$C_{grid,energy} = \sum_{i}^{rates} \sum_{j}^{12} E_{gridpurchaes,i,j} \cdot c_{power,i} - \\ - \sum_{i}^{rates} \sum_{j}^{12} E_{gridsales,i,j} \cdot c_{sellback,i} \quad (4)$$

where,

$E_{gridpurchases,i,j}$ - the amount of energy purchased from the grid in month j during the time that rate i applies [kWh];

$c_{power,i}$ - the grid power price for rate i [\$/kWh];

$E_{gridsales,i,j}$ - the amount of energy sold to the grid in month j during the time that rate i applies [kWh],

$c_{sellback,i}$ - the sellback rate for rate i [\$/kWh].

The minus sign for the energy exchanged with the network means that the amount of energy sold in the network is greater than energy purchased from the grid.

Table 3. Energy change - Case 1

Month	Energy Purchased	Energy Sold	Net Purchases	Peak Demand	Energy Charge
	(kWh)	(kWh)	(kWh)	(kW)	(kWh)
Jan	4587	1189	3398	23	680
Feb	2635	3671	-1036	17	-207
Mar	2682	7356	-4674	17	-935
Apr	1718	10365	-8647	16	-1729
May	2145	5527	-3382	15	-676
Jun	2398	3046	-648	17	-130
Jul	2501	2329	172	15	34
Aug	3460	2106	1354	20	271
Sep	3149	2370	779	18	156
Oct	2825	2136	689	16	138
Nov	2811	1822	988	15	198
Dec	4631	893	3738	22	748
Annual	35542	42811	-7269	23	-1454

Table 4. Energy change - Case 2

Month	Energy Purchased	Energy Sold	Net Purchases	Peak Demand	Energy Charge
	(kWh)	(kWh)	(kWh)	(kW)	(kWh)
Jan	4537	1231	3306	23	661
Feb	2559	3746	-1187	17	-237
Mar	2569	7514	-4945	17	-989
Apr	1611	10616	-9005	16	-1801
May	1928	5836	-3908	15	-782
Jun	2134	3355	-1222	17	-244
Jul	2215	2587	-373	15	-75
Aug	3202	2311	892	20	178
Sep	3009	2509	500	18	100
Oct	2735	2211	524	16	105
Nov	2786	1899	887	15	177
Dec	4583	918	3664	22	733
Annual	33868	44732	-10864	23	-2173

Table 5 and 6 presents the investments, the replacement and the maintenance costs repartition for each component of the hybrid renewable energy system.

Table 5. Total net present cost - Case 1

Comp	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
PV	15000	0	2723	0	0	17723
E33	100000	0	22693	0	0	122693
Grid	0	0	-13196	0	0	-13196
Conv.	9000	2155	0	0	-277	10878
System	124000	2155	12220	0	-277	138097

Table 6. Total net present cost - Case 2

Comp	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
PV	20000	0	2723	0	0	22723
E33	100000	0	22693	0	0	122693
Grid	0	0	-19723	0	0	-19723
Conv.	9000	2155	0	0	-277	10878
System	129000	2155	5693	0	-277	136570

5. CONCLUSION

Wind turbines and photovoltaic panels are considered to be energy sources of the future. Interest in this field is increasing in recent years due to the negative consequences identified by using conventional fuels to produce electric energy. Among these consequences an important aspect is represented by the environmental impact.

Using a hybrid system with renewable energy sources depends on the location where you want to implement it, it is different from one area to another as wind speed and solar radiation differs in Romania. Therefore, an optimally sized system in southern Romania can be inappropriate in northern Romania, the weather condition is different from one area to another. That is why when using a renewable energy system it is taken into account the local weather conditions.

The use of power systems under 1 MW are intended to:

a) promote the use by the final consumers of renewable energy sources for electricity production for their own consumption,

b) decrease in costs related to electric energy consumption at final consumers,

c) reducing electric power losses due to transmission and distribution, as a result of electric energy production to the place of consumption.

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