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# Optimization and Analysis of a Hybrid system in Tromso, Norway by using HOMER Software

Gelareh Hajian, Mohammad Saeed Ahadi, Mohamadreza eskandari

**Abstract**— In the cold climate of Nordic countries (Sweden, Finland, Denmark and Norway) energy is vital for survival. The scarcity and uneven distribution of energy resources, rising energy prices and concern for climate change have all contributed to growing global need for energy efficiency and increased use of renewable energy resources. In this paper PV-Wind-Hybrid systems have been studied in Tromso, Norway. The load is considered as a remote load, where grid connection is almost not possible, because of the various issues such as the high price of using transmission line or the difficulties in providing electricity from power line, so using energy generation system can be a reliable and optimized source of energy in such cases. The study has been performed with the simulation tool: HOMER software which is developed by the National Renewable Energy Laboratory (NREL) for techno-economic feasibility studies of hybrid systems. Here, HOMER is used to examine the most cost effective configurations among set of systems for electricity requirement of 53 KWh/day primary remote load with 7.8 kW peak load in order to obtain the most feasible configuration of a hybrid renewable energy system. Meteorological data about solar radiation throughout a year and wind speed in the Tromso city are taken from RETScreen software.

**Index Terms**— Hybrid system, Renewable energy, HOMER, Sensitivity Analysis.

## 1 Introduction

Since solar, wind and tidal energies mainly depend upon statistical parameters with respect to changing climate and environment, focus on hybrid generation system design increases the availability of the power generation system. The hybrid system also reduces the dependence on one environment parameter thus providing the consumer with reliable and cheap electricity [1]. For example, the wind and solar energy which are individually less reliable could have a higher reliability when used together. [2] In the past, the hybrid systems have been considered as preferred for remote systems like radio telecommunication and satellite earth stations. [3, 5, 10] These days, in remote areas, where grid connection is almost not possible, renewable energy generation system can be a reliable and optimized source of energy for households and other usages because these two sources of energies are able to compensate each other minima. The combination of solar and wind should be especially favorable for locations at high latitudes such as Nordic countries with a very uneven distribution of solar radiation during the year.[3] Therefore, it is better to use hybrid systems than stand-alone PV systems in Nordic countries, because of the uneven distribution of the solar radiation causing high costs in PV-alone system, if the system needs to be sized for a constant load throughout the year. While, the average wind power at the most locations in Nordic countries is higher during the seasons with low irradiation, hybrid system can compensate the low irradiation of solar during these periods.


- *Gelareh Hajian, Master of Science in electrical engineering, Razi University, Iran, PH-+989188327870. E-mail: gelareh.hajian85@gmail.com.*
- *Mohamad Saeed Ahadi, Master of Science in civil engineering, Tehran Polytechnic, Iran, PH-+989183330431. E-mail: Mohammadsaeedahadi@gmail.com.*
- *Mohamadreza eskandari, Master of Science in electronic engineering, Razi University, Iran, PH-+989183390379. E-mail: Reza.eskandari126@gmail.com.*


## 2 Energy Resources for Hybrid Power System

The hybrid system consists of renewable energy sources: solar and wind energy, an electrical load, and other system such as solar array, wind turbines, battery and converter. For this hybrid system, the meteorological data of Solar Radiation and monthly wind speed are taken for Tromso which is located in Latitude 69.7° North and Longitude 18.9° East.

## 3 Solar Energy:

In this study, monthly average global radiation data has been taken from RETScreen software which is used NASA (National Aeronautics and Space Administration) data. Tromso has an average annual daily solar radiation 1.79 Kw/m²/d.

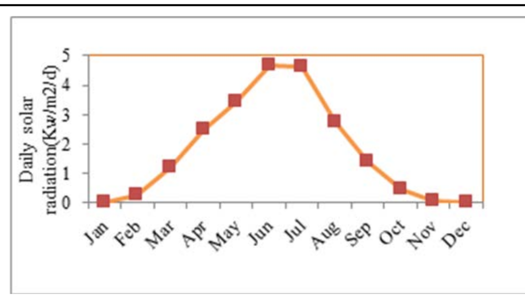


Fig. 1. Solar radiation data throughout the year.

## 4 Wind Energy:

Wind speed also varies seasonally. Average wind speed of the mentioned area is 4.3 m/s. These data were collected from

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RETScreen Software.

According to below graph, Tromso has an appropriate potential for using wind and solar power together. As can be seen, during the seasons in which the solar irradiance is low, the power of wind is high, as well as in seasons with better solar radiation; the wind power has less speed. Therefore, installing hybrid system can be more effective.

## 5 Purpose of the Report:

In this report a PV-Wind-Hybrid system has been studied in Tromso, Norway. The aim was to analysis of a several hybrid energy system models for optimization. The analysis of the hybrid systems are modeling in the HOMER software which was utilized as the assessment tool with modeling performed with hourly load data. In this study, a discussion of the cost optimization analysis of a hybrid energy generation system is performed. Here, HOMER is used to examine the most cost effective configurations among a set of systems for electricity requirement of 53 KWh/day primary load.

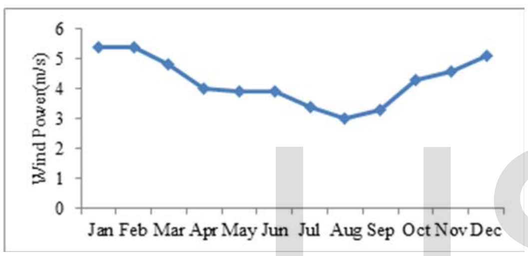



Fig. 2. Wind Speed data throughout the year.

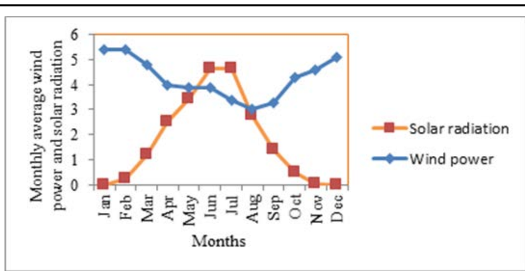



Fig. 3. Monthly average wind power at 10 m height and monthly average horizontal solar radiation in Tromso.

## 6 Hybrid PV-Wind Energy System:

The hybrid generation system consists of an electrical load, renewable energy sources and other system components such as PV, wind turbines, battery and converter. Fig.4 shows the hybrid energy renewable system in HOMER software.

The system size has been limited to 35 Kw PV power and 30 kW wind turbine power. A load which is considered as a remote load is a 53 Kwh/d with the peak of 7.8 kW. Fig 5 shows the load profile on a day.

The hybrid system is designed to meet the electrical demands of this load.

## 7 PV Array:

The costs of PV arrays are based on their technology. The PV array which is considered in this work, has the size from 1 to 35Kw. HOMER will simulate the system within the given range and will give the output with the optimal size of PV. The cost of installing a solar system is considered around $2 per watt, therefore, 1 kW PV array cost was assumed to be $2000 and the replacement cost was considered 1500$. Operating and Maintenance costs are not high for a PV system.

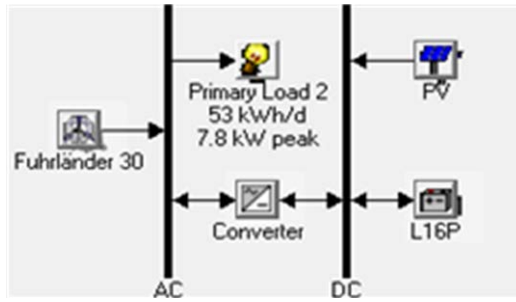



Fig. 4. Complete hybrid energy renewable system.

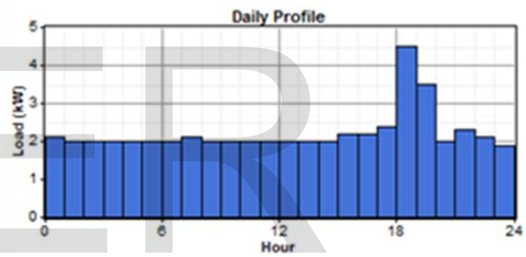



Fig. 5. Daily load profile

## 8 Wind Turbine:

The technical parameters of selected wind turbine (Fuhrlander 30) are stated in table1. The capital cost and replacement cost are assumed 68000$ and 20000$ respectively. (The prices of capital and replacement cost for Fuhrlander 30 turbine were asked from Fuhrlander Company.) Some parameters which are considered in HOMER for wind source are:

1)Weibull k Value: The Weibull k value, or Weibull shape factor, is a parameter that reflects the breadth of a distribution of wind speeds. Lower k values correspond to broader wind speed distributions. So a very gusty location may have a Weibull k value as low as 1.5 or so, whereas a location characterized by very steady winds (like tropical trade wind environments) may have a k value as high as 3 or 4. So The Weibull k value is taken 1.6 in this report.

2) Autocorrelation Factors: According to the HOMER softwareThe complexity of local topography has a significant effect on the autocorrelation factor. Areas surrounded by a variety of different types of topography tend to have low (0.70 - 0.80) autocorrelation factors. The topography around Tromsø is extremely varied. High mountains mean that thick snow can be

falling on one side, while stars glitter in the clear, biting cold on the other. It means that in the Tromsø region, you can find very different weather conditions by driving relatively short distances. So the autocorrelation factor is taken 0.75.

3) The diurnal pattern strength: is a number between 0 and 1 that reflects how strongly the wind speed tends to depend on the time of day. Higher value s indicates that there is strong dependence on the time of the day. In this study, 0.3 is used.

4) Hour of Peak Wind speed: The hour of peak wind speed is the hour of the day that tends to be the windiest, on average (Typical Range: 14-16) 15 is used in this study.

TABLE I
SPECIFICATIONS OF WIND TURBINE

| POWER | | | Unit |
|---|---|---|---|
| 1) | Rated power | 30 | Kw |
| 2) | Rated wind speed | 12 | m/s |
| 3) | Cut-in wide speed | 2.5 | m/s |
| 4) | Cut-out wind speed | 25 | m/s |
| 5) | Maximum wind speed the turbine can withstand | 55 | m/s |
| DIMENSIONS | | | |
| 6) | Rotor weight | 640 | kg |
| 7) | Rotor diameter | 13 | m |
| 8) | Rotor height (for VAWT only) | | m |
| 9) | Swept area | 133 | $m^2$ |
| 10) | Height of the mast | 18/27 | m |

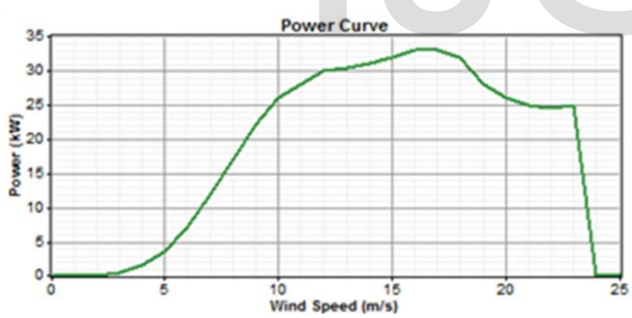
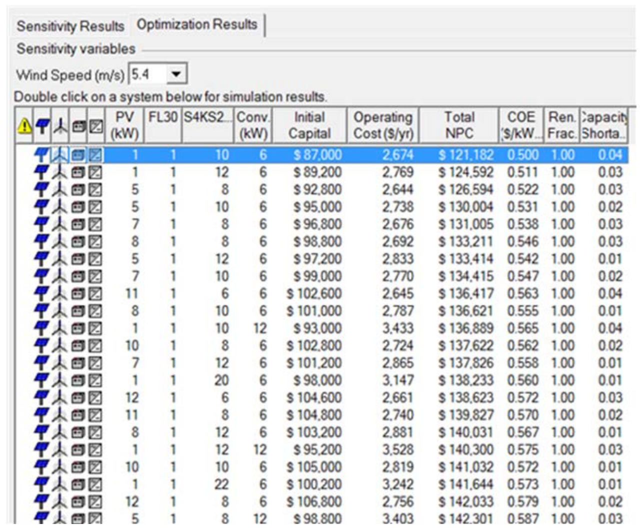



Fig. 6. Power curve of Fuhrlander 30Kw wind turbine.

## 9 RESULTS AND DISCUSSION:

Simulation results which include each component size, each system configuration's costs and total net present cost of the first some optimal combinations are shown in Fig 7. Lots of simulations have been done to find out the most optimized and cost effective configuration of the hybrid system. In simulation Results by clicking on each of the displayed solution we can access a comprehensive set of data providing high level of detail on each system component. In addition it is possible to display many economical information essential to run a thorough business case. Above list presents of different configurations with respect respective of cost/ KWh and NPC (Net Present Cost). The combination of a PV array (1KW), a wind turbine (30 KW), and 10 Surrehe 4ks25p batteries is economically organized with the minimum COE 0.5 $ /Kwh and a minimum NPC of $121.182, with 4% annual energy shortage. (This optimized configuration is an appropriate in situation in which the wind speed is considered as 5.4).



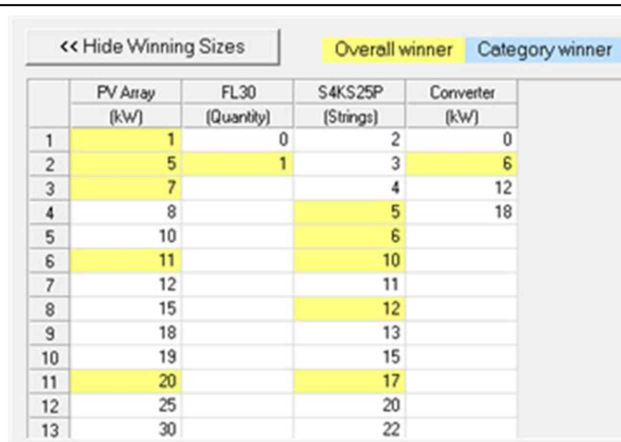
Sensitivity Results | Optimization Results
Sensitivity variables
Wind Speed (m/s) 5.4
Double click on a system below for simulation results.

| PV (kW) | FL30 | S4KS2... | Conv. (kW) | Initial Capital | Operating Cost ($/yr) | Total NPC | COE ($/kW... | Ren. Frac. | Capacity Shorta... |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 10 | 6 | $ 87,000 | 2,674 | $ 121,182 | 0.500 | 1.00 | 0.04 |
| 1 | 1 | 12 | 6 | $ 89,200 | 2,769 | $ 124,592 | 0.511 | 1.00 | 0.03 |
| 5 | 1 | 8 | 6 | $ 92,800 | 2,644 | $ 126,594 | 0.522 | 1.00 | 0.03 |
| 5 | 1 | 10 | 6 | $ 95,000 | 2,738 | $ 130,004 | 0.531 | 1.00 | 0.02 |
| 7 | 1 | 8 | 6 | $ 96,800 | 2,676 | $ 131,005 | 0.538 | 1.00 | 0.03 |
| 8 | 1 | 8 | 6 | $ 98,800 | 2,692 | $ 133,211 | 0.546 | 1.00 | 0.03 |
| 5 | 1 | 12 | 6 | $ 97,200 | 2,833 | $ 133,414 | 0.542 | 1.00 | 0.01 |
| 7 | 1 | 10 | 6 | $ 99,000 | 2,770 | $ 134,415 | 0.547 | 1.00 | 0.02 |
| 11 | 1 | 6 | 6 | $ 102,600 | 2,645 | $ 136,417 | 0.563 | 1.00 | 0.04 |
| 8 | 1 | 10 | 6 | $ 101,000 | 2,787 | $ 136,621 | 0.555 | 1.00 | 0.01 |
| 1 | 1 | 10 | 12 | $ 93,000 | 3,433 | $ 136,889 | 0.565 | 1.00 | 0.04 |
| 10 | 1 | 8 | 6 | $ 102,800 | 2,724 | $ 137,622 | 0.562 | 1.00 | 0.02 |
| 7 | 1 | 12 | 6 | $ 101,200 | 2,865 | $ 137,826 | 0.558 | 1.00 | 0.01 |
| 1 | 1 | 20 | 6 | $ 98,000 | 3,147 | $ 138,233 | 0.560 | 1.00 | 0.01 |
| 12 | 1 | 6 | 6 | $ 104,600 | 2,661 | $ 138,623 | 0.572 | 1.00 | 0.03 |
| 11 | 1 | 8 | 6 | $ 104,800 | 2,740 | $ 139,827 | 0.570 | 1.00 | 0.02 |
| 8 | 1 | 12 | 6 | $ 103,200 | 2,881 | $ 140,031 | 0.567 | 1.00 | 0.01 |
| 1 | 1 | 12 | 12 | $ 95,200 | 3,528 | $ 140,300 | 0.575 | 1.00 | 0.03 |
| 10 | 1 | 10 | 6 | $ 105,000 | 2,819 | $ 141,032 | 0.572 | 1.00 | 0.01 |
| 1 | 1 | 22 | 6 | $ 100,200 | 3,242 | $ 141,644 | 0.573 | 1.00 | 0.01 |
| 12 | 1 | 8 | 6 | $ 106,800 | 2,756 | $ 142,033 | 0.579 | 1.00 | 0.02 |
| 5 | 1 | 8 | 12 | $ 98,800 | 3,403 | $ 142,301 | 0.587 | 1.00 | 0.03 |

Fig. 7. HOMER simulation results

## 10 WINNING SIZES:

After HOMER's calculations are complete, the optimal systems are shown as winning sizes. Gold-colored values appeared in the optimal system for at least one sensitive case. In this study, wind speed is considered as sensitive parameter. Therefore, each of these winning sizes matches with the sensitivity variables of wind speed. (Values of wind speed as a sensitive parameters are considered: 3, 3.4, 4, 4.3, 5, 5.1, 5.4).



<< Hide Winning Sizes | Overall winner | Category winner

| | PV Array (kW) | FL30 (Quantity) | S4KS25P (Strings) | Converter (kW) |
|---|---|---|---|---|
| 1 | 1 | 0 | 2 | 0 |
| 2 | 5 | 1 | 3 | 6 |
| 3 | 7 | | 4 | 12 |
| 4 | 8 | | 5 | 18 |
| 5 | 10 | | 6 | |
| 6 | 11 | | 10 | |
| 7 | 12 | | 11 | |
| 8 | 15 | | 12 | |
| 9 | 18 | | 13 | |
| 10 | 19 | | 15 | |
| 11 | 20 | | 17 | |
| 12 | 25 | | 20 | |
| 13 | 30 | | 22 | |

Fig. 8. Winning Sizes results

For example, HOMER winning sizes for the wind speed is 5.4 (m/s) are: PV Array (1 Kw), wind turbine (30 KW), and 10 Surrehe 4ks25p batteries and NPC $121.182, while the winning

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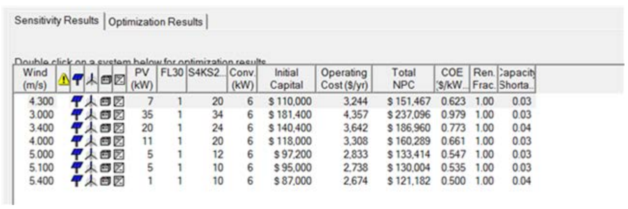
sizes for situation in which wind speed is 4 are: PV Array (11 Kw), wind turbine (30 KW), and 20 Surrehe 4ks25p batteries. In addition, the winning sizes for an annual average wind speed 4.3 are PV Array (7Kw), wind turbine (30 KW), and 20 Surrehe 4ks25p batteries. In Fig 9 all the sensitivity results by considering the various wind speed are shown according to having the minimum NPC.



Sensitivity Results | Optimization Results

Double click on a system below for optimization results

| Wind (m/s) | PV (kW) | FL30 | S4KS2... | Conv. (kW) | Initial Capital | Operating Cost ($/yr) | Total NPC | COE ($/kW... | Ren. Frac. | Capacity Shorta... |
|---|---|---|---|---|---|---|---|---|---|---|
| 4.300 | 7 | 1 | 20 | 6 | $ 110,000 | 3,244 | $ 151,467 | 0.623 | 1.00 | 0.03 |
| 3.000 | 35 | 1 | 34 | 6 | $ 181,400 | 4,357 | $ 237,096 | 0.979 | 1.00 | 0.03 |
| 3.400 | 20 | 1 | 24 | 6 | $ 140,400 | 3,642 | $ 186,960 | 0.773 | 1.00 | 0.04 |
| 4.000 | 11 | 1 | 20 | 6 | $ 118,000 | 3,308 | $ 160,289 | 0.661 | 1.00 | 0.03 |
| 5.000 | 5 | 1 | 12 | 6 | $ 97,200 | 2,833 | $ 133,414 | 0.547 | 1.00 | 0.03 |
| 5.100 | 5 | 1 | 10 | 6 | $ 95,000 | 2,738 | $ 130,004 | 0.535 | 1.00 | 0.03 |
| 5.400 | 1 | 1 | 10 | 6 | $ 87,000 | 2,674 | $ 121,182 | 0.500 | 1.00 | 0.04 |

Fig. 9. Winning Sizes according to sensitivity variables.

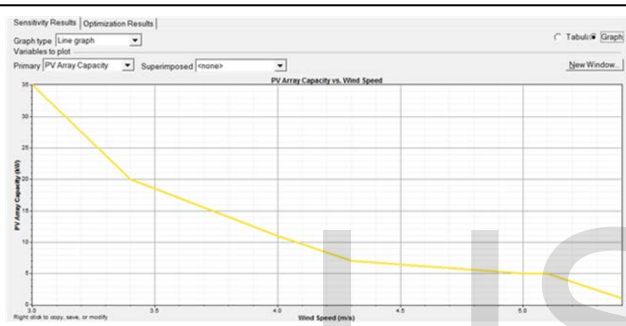



Fig. 10. the relation between PV array and wind speed.

As can be seen in this graph, the amount of PV array is increasing by the decreases in the rate of wind speed. Therefore, the choice of appropriate configuration is a complex trade-off among financial, renewable, technical and design requirements. For example, a hybrid system which is selected to meet the load demands in this study is considered in worse condition in which the wind speed has its minimum speed during the year:3m/s and the winning sizes for this condition are PV Array (35Kw), wind turbine (30 KW), and 34 Surrehe 4ks25p batteries with COE 0.979$/kw.

These parameters which are calculated by HOMER software as a winning size are the best option economically for this study in which the wind speed is the lowest (3m/s).

## 11 CONCLUSION:

This paper presented a proposed hybrid power system for a remote load site where the grid extension is not feasible, in Tromso, Norway. System sizing and designed system configuration is presented. A particular aim of this study was to show that at a site in Nordic countries where solar and wind resources are available has the potential to meet the electricity load demands, while other resources like oil, coal and so on are not used to produce energy. It was shown that the obtained optimal configuration of the hybrid wind-PV-battery system could overcome the effect of the climatic change on the reliable supply of the load.

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