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HYBRID POWER SUPPLY SYSTEM

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Abstract: *Hybrid power supply systems in the recent time are used in everyday life, primarily because humanity turns in exploitation of renewable energy sources, as well as the reduction of fossil fuel reserves, where most of the electricity produced is based. The hybrid power supply system in its most general form includes the following components: photovoltaic systems, wind generator, diesel generator, a system for energy storage (batteries), grid connection, and power converters through which is perform the conversion of electrical energy and power suppling. This paper will provide an analysis of the operation and viability of a hybrid power supply system, modeled in software package HOMER.*
Keywords: *renewable energy, hybrid power supply system, energy efficiency*

INTRODUCTION

The energy crisis, which is reflected in the increasing prices of fossil fuels, raises the question of ensuring the safety and operation of power systems ranging from small communities, cities, regions and even countries. The growing energy demand lead to the introduction of energy saving measures, implementation of energy efficiency policies and the need for renewable energy sources, which are the foundation of sustainable development in meeting energy demands.

The main energy sources in the twentieth century were nonrenewable energy sources: coal, oil, natural gas and nuclear energy. Two main problems of non-renewable energy sources are the facts that have them in limited quantities and that pollute the environment. The burning of fossil fuels releases large amounts of CO_2, which caused global temperature increase on Earth. Nuclear fuels are not dangerous for the atmosphere, but the resulting products of nuclear reaction remain radioactive for years, and should be stored in separate rooms. Renewable energy sources represent an inexhaustible natural form of energy that is all around us. The concept of renewable energy sources means energy sources that can be found in nature, and it can be renewed completely or partially. Natural and technical potential of renewable energy sources is sufficient to satisfy the overall energy requirements of the world's population, because their natural daily potential is 20 000 times higher than the daily consumption of nuclear and fossil fuels. Renewable energy sources there are in huge amount, but the current technology development does not allow complete reliance only on them.

Hybrid power supply systems, in the recent time, are used in everyday life, primarily because humanity turns in exploitation of renewable energy sources, as well as the reduction of fossil fuel reserves, where most of the electricity produced is based. The hybrid power supply system in its most general form includes the following components: photovoltaic systems, wind generator, diesel generator, a system for energy storage (batteries), grid connection, and power converters through which is perform the conversion of electrical energy and power suppling [1].

As an example of softwere/programe which can analyse all aspects of benefits/disadvantages of a hybrid power supply system, such as cost-effectiveness of the system, designing, electricity production, the losses in the system, is described HOMER, software that was developed by NREL-a (National Renewable Energy Laboratory) and represent a computer optimization model for distributed generation of electricity.

The paper describes a concrete example of a hybrid power system that aims to provide power consumers (residential units) at the site of Sarajevo. The system is designed as an "off-grid" configuration, providing the variant of analysis with connection to the distribution grid.

THE CONCEPT OF THE HYBRID SYSTEM

As it noted earlier, the most widely used configuration of the hybrid power system is one of a combination of electricity sources represented by blocks of wind generator, photovoltaic modules, diesel engine as an additional source of energy and the possibility of connection to the grid through a converter which provide electricity supply to consumers. Block diagram of such a system is shown in Figure 1.

Wind energy is the fastest growing segment of energy production from renewable sources. On a very windy locations, wind farms can produce energy at a cost that is comparable to those in the most economical traditional generators. Due to the advancement in technology, mass production and experience, wind energy is a form

of energy from renewable sources, which will over the next decade give the largest contribution to electricity production. As a good sides of using wind energy stand out the high reliability of plant operation, no fuel costs and no pollution. Bad sides are high construction costs and the variability of wind speeds (can not guarantee the delivery of energy).

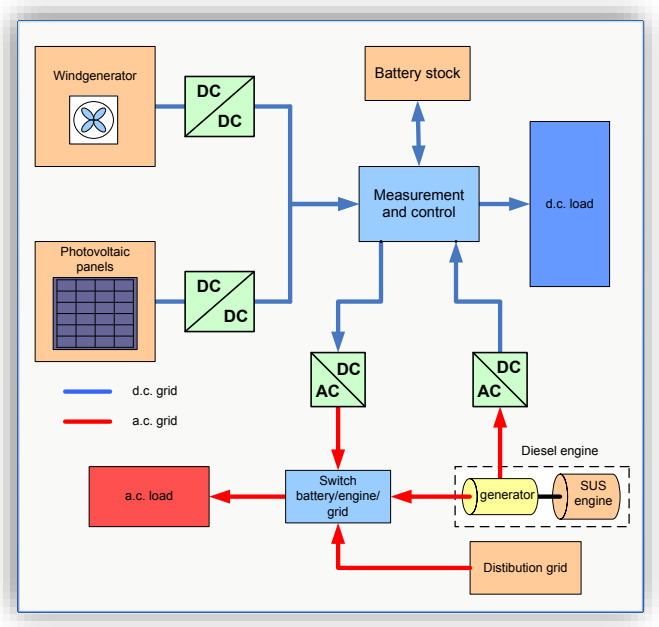


Figure 1. Structure of the hybrid power supply system

Wind generator consists of a wind turbine that converts the kinetic energy of the wind into mechanical energy, and electric generator which converts mechanical energy into electricity. Generators are set at a top of cylindrical or lattice pillar, wherein the rotor of wind turbine and rotor of electric generator mounted on a common shaft, with or without an appropriate gear. Wind generator is designed to give rated output power at the rated wind speed. For wind speeds below the cut-in wind speed, wind turbine is out of work since developed aerodynamic torque is not sufficient to overcome the losses due to friction engines, and to produces usable power. For wind speeds above the rated, power is aerodynamically controlled to maintain output at rated value until it reaches some limiting values of wind speed, known as the cut-off speed, at which point the wind turbine stops. The relationship between power and wind speed is known as the power curve [2,3]. A typical example of the power curve and the power factor of a wind turbine is shown in Figure 2.

The photovoltaic system is an integrated set of photovoltaic modules and other components, designed so that the primary solar energy directly transform into electricity which ensures the certain number of d.c. / a.c consumers are supplied. For photovoltaic systems connected to the distribution grid, direct current obtained in the photovoltaic modules is converted into alternating current by the inverter, which is connected to the grid, so that beside of supplying the consumers and performs energy exchange with the grid. Design of photovoltaic systems is usually done on the basis of their annual energy produced, which is also a good parameter for monitoring the long-term performance of photovoltaic systems. To predict annual energy production of photovoltaic systems are essential to have reliable models and methods with respect to the stochastic nature of solar radiation and the large number of influencing factors (environmental conditions and system performance).

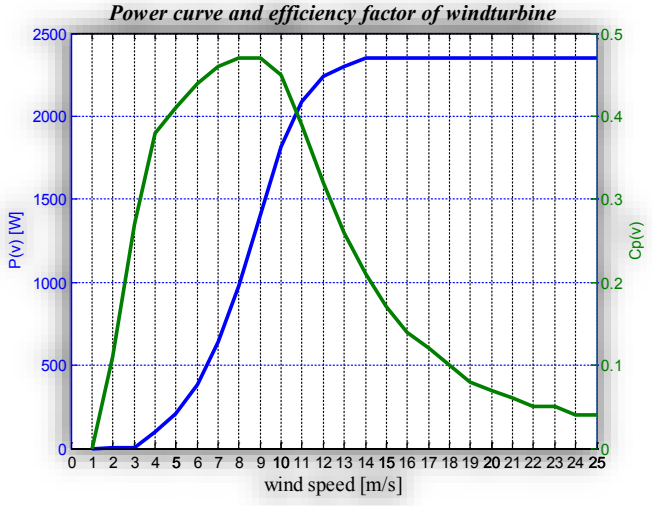
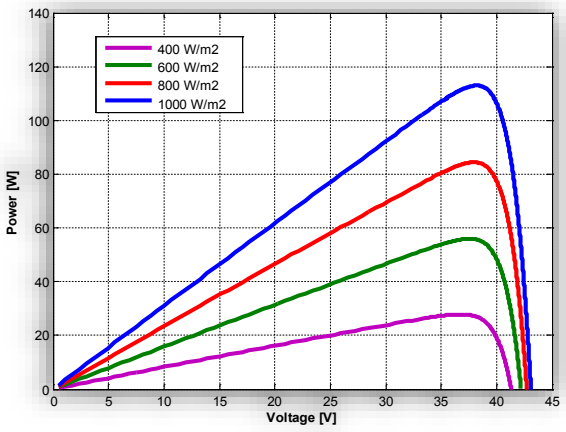


Figure 2. Power curve and efficiency factor of windturbine



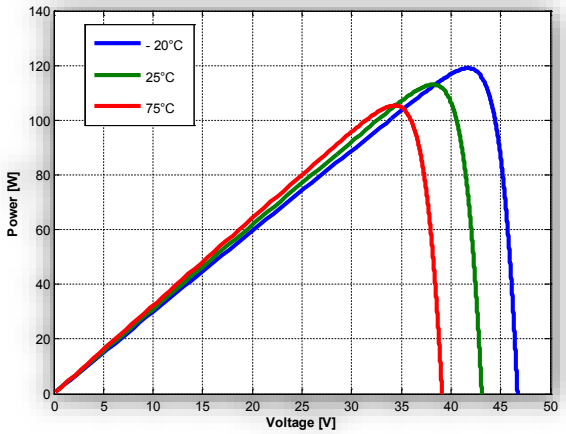


Figure 3. Photovoltaic power curve due to changing the solar radiation and changing the temperature

In order to design a grid connected photovoltaic systems, solar energy resources, environmental conditions, and characteristics of all elements of system must be well acquainted. Estimate of solar energy

resources is based on measurements and calculations based on solar radiation at the surface on which it is planned to set up the panel. In order to estimate system performance, the rated DC power output of an individual module under standard test conditions (irradiation of 1 kWh/m^2, air mass ratio AM 1.5, cell operating temperature 25^{o}C, modules completely clean) can be used at the beginning of process [3]. In real operating conditions, output power of photovoltaic system delivered to the grid is less than the d.c. output power of modules at standard conditions due to losses regarding conversion efficiency.

An example of the photovoltaic power curve due to changing the solar radiation and environmental conditions (temperature) is shown in Figure 3 [4].

APPLICATION SOFTWARE TOOL »HOMER« IN THE DESIGN OF HYBRID SYSTEMS

HOMER is the computer optimization model for distributed generation of electricity, which simplifies the task of self-assessment of cost effectiveness or grid modeled hybrid system composed of non-renewable and renewable resources. It is developted by NREL (National Renewable Energy Laboratory) at 1993. [5,8]

Over designing process of distribution grid (energy system), it is necessary to make many decisions about the configuration of the system itself. A large number of technology options and variations in technology, prices and availability of energy resources, make it difficult to choose from. Optimization algorithms and sensitivity analysis with HOMER make many possible configurations of the system. HOMER allows the definition of a model with inputs, which describe technology options, component costs, and resource availability. The program uses the entered data to simulate the system configuration, or a combination of component and generates results that are presented as a list of feasible configurations sorted by price. Simulation results in different tables and graphs help in evaluating and comparing configuration according to their economic and technical values. During the investigation of the impact/effects that make changes caused by factors such as the availability of resources and economic conditions on the cost-effectiveness of different system configurations, software performed a sensitivity analysis. When performing sensitivity analysis, HOMER requires information about the values that describe the extent of changes in the availability of funds and the price components. HOMER simulates each system configuration based on these inputs. The results of the sensitivity analysis to identify the factors that have the greatest impact on the design and operation of the system. HOMER calculates the energy balances for each configuration of the system under consideration. Specifies whether the configuration is feasible, ie. it can meet the requirements of the users, and estimates the cost of installation, operation and maintenance of the system in the lifetime of the project.

For most users, the hybrid system financial return on investment is an important indicator in the decision to invest in the project. Significant funding for the initial investment, and sometimes they are a major obstacle to the decision to invest. Therefore, optimizing the system is a key prerequisite for achieving financial viability of the hybrid system. Optimization procedure was carried out so as to form a model of the system in the software package HOMER who will be making a comparison or evaluation of small hybrid (energy) systems that can be connected to a grid or to work completely independently (stand alone) [6,7]. In the formed model it will be shown how can provide electricity from renewable sources to the consumer, and provide cost-benefit analysis if the resulting energy is used for the needs of consumers or sold to distribution companies.

For the use and formation of the model in HOMER, it is necessary to entered the input data describing the choice of technology, the price of available components, and energy resources into model. In this way it is possible to compare the economic and technical parameters of various combinations of the hybrid system with the aim of selecting the one that is optimal for specific purposes. For a concrete example, the designing the residential building supplying system on the site of Sarajevo were collected input data on available renewable resources shown in Fig. 4 and 5.

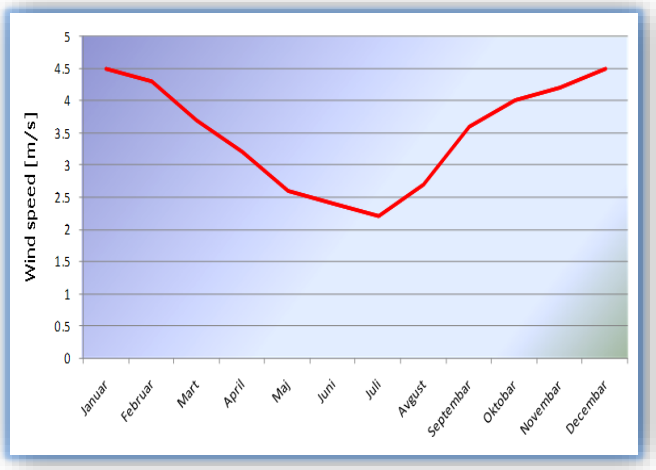


Figure 4. Average wind speed by months

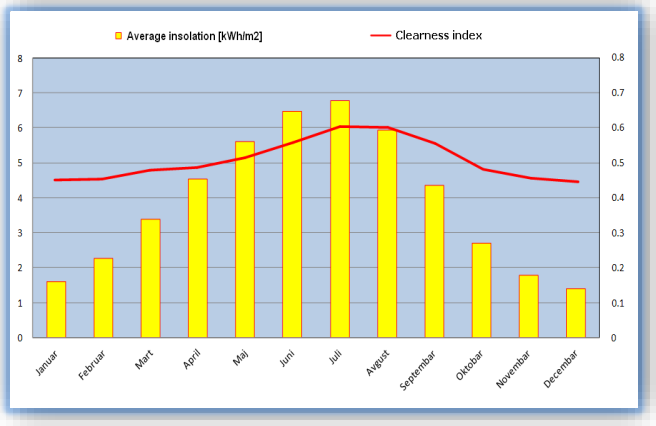


Figure 5. The data on solar radiation at the site of Sarajevo

The data on the average wind speed of 3.5 m/s shall decide on the selection of a low-power wind turbine, whose rated speed was as close as possible to the measured. Measuring height of the

anemometer is located is 10 m, and elevation of the location is 590 m. Height measurement is relatively low, which means that the rate under the dominant influence of surface roughness and facilities nearby. Wind speed at the vertical distance from the ground will bo growing which makes favorable setting up a small windgenerators on higher pillar. The values of mean daily insolation differ significantly in winter months (December 1.41 kWh/m^2) and summer (July 6.77 kWh/m^2), which results in the different production of photovoltaic systems.

Before choosing and sizing the appropriate components of system, it is necessary to know which load the system must satisfy, whether it's the connection object to the grid or on a standalone hybrid system. Depending on the consumer load and the available renewable energy sources are chosen corresponding components of the system. Figure 6 is a diagram presented daily load, which is used in this paper during the simulation of described system.

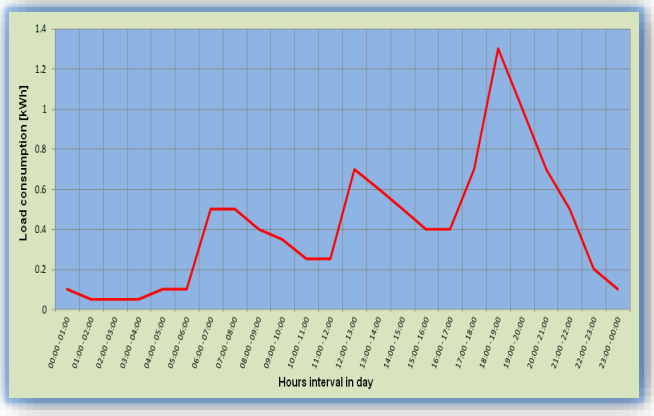


Figure 6. Diagram of the average hourly / daily load

RESULTS ANALYSIS AND DISCUSSION

Based on the analysis of the input data, it is established a model of the system in HOMER (Figure 7), which consists of the following components: photovoltaic panels, wind generator, battery pack, inverter and connected consumer.

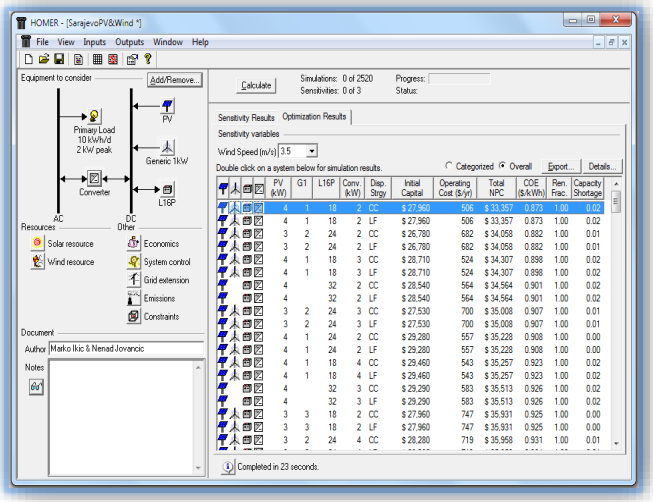


Figure 7. Results of optimization system configurations sorted by the total costs

In Figure 7, in addition to the formed models are presented and the results of simulation/optimization sorted by optimal selection of components in relation to the total cost of the system. As the best solution, ie the most cost-effective, software based on optimization model provides the configuration of the system consisting of the photovoltaic panel size 4 kW, a 1 kW wind generator, battery system of 18 batteries connected in parallel, the nominal capacity of 6480 Ah, rated voltage of 6 V and the inverter 2 kW (which in this case is only in inverter mode).

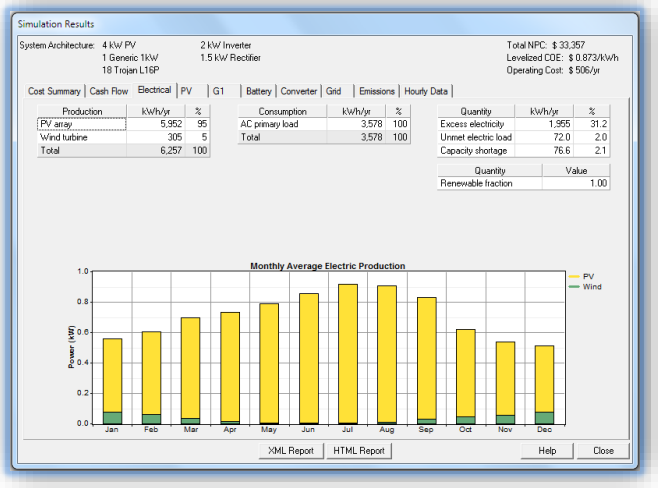


Figure 8. Total electricity generation of the hybrid system

Electricity production from this system, based on the given input parameters, is plotted in Figure 8. The total value of the electricity produced is 6257 kWh/year, of which photovoltaic panels produce 5952 kWh/year (95%) and a wind generator 305 kWh/year (5%). The required load of the system is 3578 kWh/year so it is obvious that this system meets in the provision of electricity consumers, and even has a possibility that excess energy to the distribution companies selling at prices that are subsidized by the state if there would be access to the distribution grid and thus reduce the time of repayment of formed system.

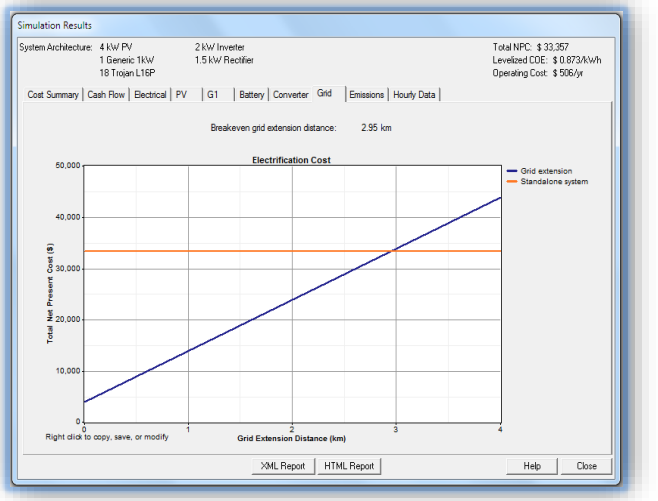


Figure 9. Graphic viability of the hybrid system and the grid connection in relation to the length of connector (fider)

If we look at the profitability of the hybrid system in relation to the possibility of connection of consumers to the distribution grid (where are previously entered data on the costs of connection and the grid price of electricity), as a result of the conducted analysis in the HOMER, is that the hybrid system is more cost-effective if the distance consumers from possible connection to the grid is greater than 2.95 km (Figure 9). In conclusion it can be said that such systems are suitable for power consumers who are more distant from the local distribution grid.

CONCLUSION

In this paper, the use of specific software HOMER in the analysis of work and the cost-effectiveness of hybrid power systems is shown. A brief overview of renewable energy, specifically the solar energy and wind energy, their exploitation and the parameters which are describe and measure them. It is described the configurations of the one hybrid system and its components as well as the benefits and disadvantages of the use in everyday life.

For the analysis of the hybrid system is described HOMER software, that carry out all analysis of the proper work of system, its viability and designing process of its components. From the general results of the system optimization model, it can be noted that this systems should also find their use in everyday life, especially in localities that are "enriched" with renewable energy sources ie. at sites with a high level of insolation and higher wind speeds as well as at the same time it is not anticipated consumer connection to the distribution grid or its implementation is more expensive than the cost of installing a hybrid system.

LITERATURE

[1] *Zvonimir Bilić: „Napajanje udaljenog stambenog objekta pomoću energije vjetra i sunčevog zračenja", Elektrotehnički fakultet Osijek, 2006.*

[2] *Thomas Ackermann: „Wind Power in Power Systems", John Wiley & Sons, Ltd, The Atrium, Southern Gate, Chichester, West Sussex PO19 8SQ, England, 2005.*

[3] *Gilbert M. Masters, „Renewable and Efficient Electric Power Systems", John Wiley & Sons, Inc., Hoboken, New Jersey, 2004.*

[4] *Marko Ikić, Nenad Jovančić: „Characteristics of PV panels depending of solar insolation and temperature conditions", Renewable energy sources, Faculty of Electrical Engineering East Sarajevo, September 2011.*

[5] *Tom Lambert, Paul Gilman, Peter Lilienthal: „Micropower system modeling with HOMER", Integration of Alternative Sources of Energy, John Wiley & Sons, Inc, May 2009.*

[6] *Souissi Ahmed, Hasnaoui Othman, Sallami Anis: „Optimal Sizing of a Hybrid System of Renewable Energy for a Reliable Load Supply without Interruption", European Journal of Scientific Research, ISSN 1450-216X Vol.45 No.4 (2010), pp.620-629*

[7] *Tiberiu Tudorache, Alexandru Morega: „Optimum Design of Wind/PV/Diesel/Batteries Hybrid Systems", 2ND International Conference on Modern Power Systems - MPS 2008, 12-14 November 2008, CLUJ-NAPOCA, ROMANIA*

[8] *www.homerenergy.com, October 2014.*

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