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[1.]C. DUMITRESCU, [2.]V. DULGHERU, [1.]C. CRISTESCU,
[1.]L. DUMITRESCU, [1.]M. BLEJAN, [1.]R. RADOI

REDUCING CONVENTIONAL FUEL CONSUMPTION BY IMPLEMENTING HYBRID ENERGY PRODUCTION SYSTEMS

[1.] National Institute for Optoelectronics, Hydraulics & Pneumatics Research Institute, Bucharest, ROMANIA
[2.] Technical University of Moldova, Mechanical Faculty, Chișinău, MOLDOVA

Abstract: Benefiting from significant renewable energy resources, Romania has made great strides in recent years in the field of converting solar and wind energy; in addition to these, hydraulic energy has been exploited for several decades. For the conversion systems of these types of energy, lately there have emerged technical solutions at competitive prices, making them accessible to smaller users as well. Thus, in remote areas, renewable energy intelligently exploited can provide autonomy in terms of energy or, in case they are used in hybrid systems, a significant reduction in costs.
Keywords: renewable energy, reducing consumption, conversion energy, hybrid system, energetic autonomy

1. INTRODUCTION

The use of renewable energy as sources of obtaining clean energy is a current concern, and for certain areas on Earth this is the only way to obtain useful (electrical, thermal, mechanical, etc.) energy in order to increase quality of life. 2015 was a very favourable year for development of renewable energy conversion systems; besides continuous technical progress recorded in increasing the efficiency of conversion systems, decrease in oil prices created pressure for reducing the cost of energy produced from renewable sources. In this context, increasing the amount of energy from renewable sources recorded significant values in almost all categories, as one can see in the following comparison table. Investments in new production capacities were of about 285 billion $. (*REN21, 2016*).

Table 1. Synthetic indicators for renewable energy for 2015, globally

Electricity	M.U.	2014	2015
Power from renewable sources (total, excluding hydropower)	GW	665	785
Power from renewable sources (total, including hydropower)	GW	1.701	1.849
Hydroelectric power	GW	1.036	1.064
Biomass energy	GW	101	106
Geothermal energy	GW	12,9	13,2
Photovoltaic (PV) solar panels	GW	177	227
Wind energy	GW	370	433
Heat			
Solar capacity and capacity of heated water	GW_{th}	409	435

As one can notice, the highest increases were registered in the use of wind power (+ 63 GW) and in the use of photovoltaic solar panels (+ 50 GW). Regarding electricity, percentage obtained from renewable sources is 23.7%, by 2015, of which 16.6% is hydropower.

Regarding the situation nationally, the installed capacity in the National Energy System on 1st of April 2015 was of 22,308 MW overall: water 6,376 MW (28.5%), coal 5,718 MW (25.6%), hydrocarbons 4.539 MW (20.3%), wind 2.953 MW (13.2%), nuclear 1.413 MW (6.3%), solar 1.208 MW (5.4%), biomass 100 MW (0.45%) and geothermal energy 0.05 MW. [http://www.digi24.ro, 2016]. On 1st of April 2016 increases were recorded in most categories of sources of electricity production, as follows: (*http://www.agerpres.ro, 2016*).

Table 2. The installed capacity of renewable energy sources (MW)

Renewable energy source	2015	2016	Increase (%)
Photovoltaic solar energy	1208	1343	11.2
Wind energy	2953	3129	6
Micro hydropower	567	588	3.7
Biomass	100	103	3

Having at its disposal a wide range of types of renewable energy, Romania met the objectives set by the 2009/28/EC Directive, also known as the 20/20/20 Directive, which provides reaching by 2020 a quota of 24% of energy from renewable energy; this target has already been reached by 1st of January 2014, when the installed electric power had a value of 4.349 MW.

2. MATERIAL AND METHOD

Despite progress in recent years in our country, there is still significant potential to increase the amounts of energy produced from renewables [Study, 2006]; this is especially important in remote areas, which are not supplied from the common electricity network. In the absence of possibilities for initial investment in conversion systems (for wind, solar, hydro energy), for most of the time electricity is provided by means of generators driven by heat engines; this solution has the disadvantage of a significant consumption of conventional fuel (Diesel fuel or gasoline).

Hydraulics and Pneumatics Research Institute (INOE 2000-IHP) is currently implementing a project on reducing the consumption of conventional fuel used to produce electricity at an isolated area target which belongs to the Ministry of Administration and Interior and is located near the bank of the Danube (mobile docking pontoon). This area target has a unique source of electricity, namely an electric generator driven by a Diesel engine with an output of approx. 10 kW. Besides electricity supplied for direct consumption, the generator charges a group of electric accumulators which provide a backup supply to consumers.

If this group of electric accumulators can be charged from a different (renewable) source, consumption of conventional fuel used for the heat engine which drives the electric generator would drop significantly; On the other hand, some consumers (of lower importance) can be powered from the renewable source, using intelligent energy distribution.

To achieve the ultimate objective (reducing fuel consumption) (*Popescu, 2010, Popescu 2013*), in the first project phase, at the end of which a basic solution must be proposed, action must be taken in these directions:

≡ determine the critical and non-critical consumers in the location;
≡ determine the renewable energy sources and their potential for use;
≡ develop the intelligent distribution algorithm and schematic diagram.

Determining the critical/non-critical consumers implies dividing the electric consumers found in the location in 2 categories, depending on their importance in meeting the role of the area target. Within the category of critical consumers there falls the specific work equipment, while within the category of non-critical consumers there fall the consumers which ensure working conditions for staff (air conditioning, food preparation, producing domestic hot water, cleanliness, operation of audio-video broadcast media for information, etc.).

Taking into account the role of each electrical consumer and operating conditions, it was determined that the electrical power needed for critical consumers is of about 5 kW, while for non-critical consumers it is 2.5 kW.

Determining the available and usable renewable energy sources is the most important work direction. Since the site is located near the banks of the Danube, on the water, theoretically it benefits of renewable energy from multiple sources: hydro, wind, solar, biomass.

Biomass energy was eliminated early in the project, because its exploitation requires, on the one hand, finding the biomass and processing it (chopping, drying), and on the other hand burning it produces only heat energy; globally, harnessing biomass is more complicated than other types of renewable energy.

Harnessing water energy, given the relatively low speed of the Danube in the area of interest, this can be done by using floating micro-hydropower plants which use kinetic energy. Energy of flowing water, for a speed of 1 m/s, is about 500 W for a section of 1 m2. [*Bostan 2007, Bostan 2011*]. To estimate the actual value one must consider Betz's coefficient – 0.593, the maximum theoretical efficiency of conversion – and also the fact that most current solutions ensure a coefficient of water kinetic energy use within the value of 0.1...0.2. [*Maican, 2015*]

A very important aspect to functionally optimize the micro hydropower plants is choosing the optimum hydrodynamic profile of blades which allows increase in the conversion factor (the Betz's coefficient) due to hydrodynamic bearing forces. The increase in the degree of conversion is also achieved by ensuring optimum position of the blade in relation to water currents in different phases of engine rotation; an orientation mechanism of blades is used for this purpose. Thus, virtually all blades (even those who move against water currents) are simultaneously involved in generating overall torque. The blades that move in the direction of water currents use both hydrodynamic forces and water pressure to generate torque. Moving against the water currents, the blades only use hydrodynamic bearing forces to generate torque. Due to the fact that the relative speed of the blades against the water current is virtually two times higher, the hydrodynamic bearing force is relatively large, and the torque generated is commensurable with the one generated by water pressure. The following figure shows the diagram of a micro hydropower plant based on kinetic effect (MHCF). (*Bostan, 2011)*

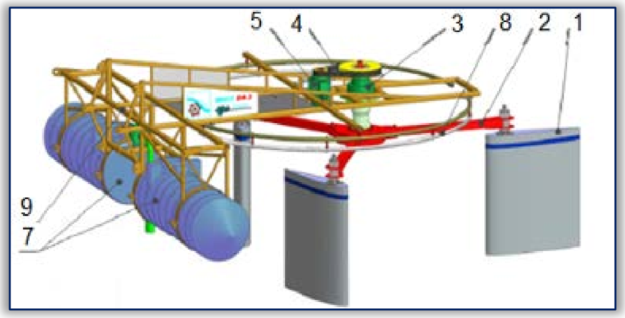

Figure 1. MHCF with hydrodynamic profile of blades
1 – blades; 2 – hydrodynamic rotor; 3 – speed multiplier;
4 – belt transmission; 5 – power generator;
6 – pump; 7 – floats; 8 – guidance device; 9 – frame

Since the flow rate of Danube does not exceed, in the most part of flowing on Romania's territory, the speed of 1 m/s, [Strechie, 2008], micro hydropower plants operating on kinetic effect could be a solution for producing energy from water. Yet another aspect that must be considered is surface freezing of the Danube in winter; this makes hydraulic energy only be considered a backup solution.

To determine the possibilities for using wind energy there have been studied maps of the area wind potential and actual measurements were performed on site, which indicated maximum speeds of up to 5 m/s (figure 2).

Figure 2. Wind speed on site

This speed is insufficient for a good functioning of classical wind turbines, which require speeds of 8...15 m/s for optimal functioning. Low speed first rises the issue of starting-up the wind turbine; to overcome this, we have considered a combined wind turbine solution, which uses a Savonius rotor for starting-up and a larger size Darrieus rotor for actually generating electricity, as one can see in Figure 3.

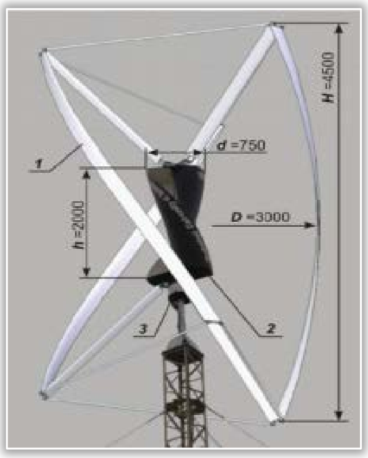

Figure 3. Mixed wind turbine, adjusted for low-speed wind
1 – Darrieus main rotor; 2 – Savonius rotor; 3 – turbine shaft

The safest renewable energy source, which has a high potential in the south of our country, is solar energy. The availability of this type of energy is confirmed both by solar potential maps, and by on site measurements, in which there have been recorded values over 1000 W/m2 for solar radiation. Another advantage of solar energy is that it can be used both to obtain heat energy (using thermal solar panels), and electrical energy, by using photovoltaic panels. Solar energy can be combined with hydro or wind energy, depending on the level to which reducing fuel consumption is intended and of course depending on the value of the investment that can be done.

3. RESULTS

Taking into account the analysis conducted so far, it is expected that solution that will be proposed will be based on solar energy, to which we can add hydro and/or wind energy. The figure below shows the block diagram of the electrical installation which will be proposed for implementation, in which the current electrical energy source (generator set consisting of electric generator and drive heat motor) is combined with a system of photovoltaic solar panels, to which we can add one or several sources of renewable energy (synthetically represented by a wind turbine), resulting in a hybrid energy system.

Compared to the current situation, on the block diagram, the battery charge controller, connection box and energy source have been added.

The battery charge controller provides charging of the existing accumulators from renewable sources, thus reducing the demand on the generator set and enabling consumption of a quantity of electricity produced from renewable sources.

The connection box ensures the connection of strings of photovoltaic panels / wind turbines to the battery of accumulators charge controller.

To increase energy efficiency of photovoltaic panels and thermal solar panels are needed orientation/ guidance systems called trackers, which maximize the amount of solar energy collected, by adjusting the position of the solar panel, tacking the apparent movement of the sun during the day (figure 4, 5). Usually, drive of solar panels is done by means of electric, pneumatic or hydraulic systems/ trackers [Şerban, 2012].

In the specialized literature there are three types of solar orientation systems: the equatorial system, the pseudo-equatorial system and the azimuth system.

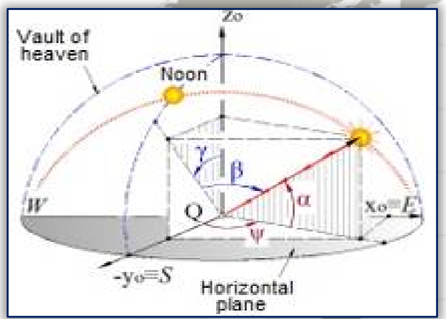

Figure 4. Global and local reference systems and sun angles corresponding to the equatorial system

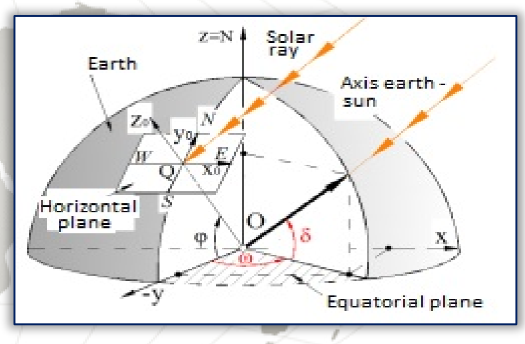

Figure 5. Global and local reference systems and sun angles corresponding to the pseudo-equatorial and azimuth systems

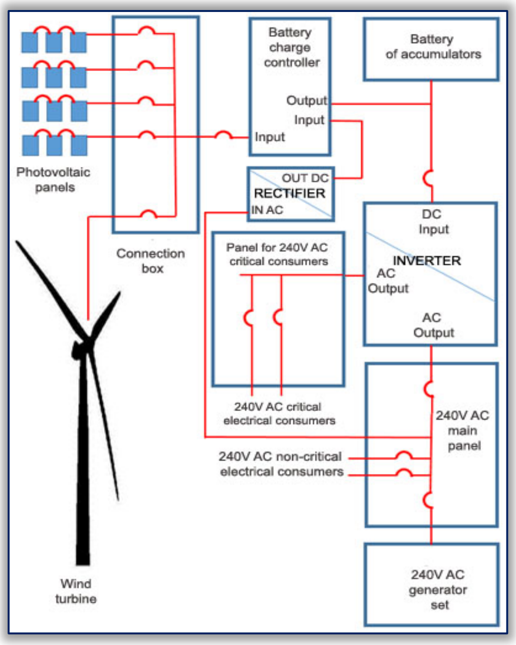

Figure 6. Schematic diagram of the electrical installation with renewable and classical source

CONCLUSIONS

From the materials presented above in this paper the following conclusions can be drawn:

- The renewable energy which has the highest potential for use is solar energy; this is clear from both the solar potential map, and from direct measurement on site, where a value of 1015 W/m^2 has been recorded; means of converting solar energy for producing heat and electricity can be developed in our country at competitive prices, out of components available on the market;
- Solar energy can be used both for producing electrical energy, using photovoltaic (PV) solar panels, and for obtaining heat energy by using thermal solar panels; producing both types of energy leads to lower fuel consumption;
- Wind energy, although present in the area of interest, is characterized by wind values below 5 m/s, which makes it unsuitable for use, given that common speeds are in the range 8…15 m/s; on the other hand, since the target areas are located at the shore, high roughness of the land causes wind speed to have a high degree of variability;

- The low speed of Danube, all along its length (max. 1 m/s), makes the placement of floating micro hydropower plants uneconomical; add to this the threat of damaging them in winter time, because of frost;
- The space that can be used allows very good conditions for placing solar panels, either thermal or electric, there being available an area of approx. 50 m^2 for placing the panels; on this area there can be installed two solar thermal panels, with a standard surface area of approx. 2 m^2, and the remaining area can be used for mounting of photovoltaic panels.
- Reducing fuel consumption used at the location in order to produce electricity by using renewable sources is feasible, being supported by the large amount of renewable energy in the work areas, especially solar energy; the estimated percentage at this stage of the project, which will have to be confirmed in the actual design phase, is 20…35%., depending on the value of the future investment.

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