Renewable energy sources used in small installations to produce electricity and to provide water for domestic supply and irrigation

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Abstract: In the paper are shown some examples of the use of renewable energy sources in different field of application. First is presented a wind turbine with vertical axis helical rotor shape that has shown good energetic performances even at low wind speed. This type of turbine can be mounted on the roof of houses making them independent energetically throughout the entire year. Secondly, is shown a wind turbine with horizontal axis which is used to pump water for domestic supply in an area of a small holiday location. It is a place with a few buildings which are located near a river and is needed water for daily requirements. For this reason was designed and realized a wind turbine that acts a diaphragm pump and which take water from a river and send it to a tank from where it is sending anytime where is needed. Finally, is presented a study and experimental achievements with an installation to prepare domestic warm water with solar panels in a area of block of flats in the town. By implementing this system on the roof of a thermal station, was reduced the gas consumption with 30 %.

Key words: wind turbine, domestic water, renewable energy, solar panel, warm water, consumption gas reduction.

1 Introduction

Renewable energy is *plentifully* available all around us every day, and they are no particular technical obstacles to harnessing it. Wind and water power have been in use long before the invention of combustion engines, and it seems likely that they will be the chosen technology in the future, when we shall have to reduce our unsustainable reliance on fossil fuels. Renewable energy production causes no CO_2 emissions nor does it consume fuel resources, after the initial manufacture and installation of the turbines, solar panels and infrastructure required. Using renewable energy frees us from dependence on imported fuels, and sets an example for developing countries.

The *biggest problem* with renewable energy is the high capital cost. The energy is diffuse and demands large structures to collect and convert it. The equipment is expensive and comes with a large amount of infrastructure. There is an energy cost associated with manufacturing renewable energy output. The time required has to be redeemed before it can be said to produce a net energy output. The time required to pay back the energy cost of manufacture is generally quite small in terms of the life expectancy of the system (often less than one year) but it can be longer in the case of small systems.

Environmental impact is the next big problem when we intend to use renewable energy sources.

Wind turbines for example are visually prominent by nature, and will change the character of the landscape to an extend. Some people like to see them, and others do not. Hydro system diverts water from its natural course into pipes and through turbines. This will have some impact on the ecology and amenity of the watercourse. These impacts must be weighed up against the impacts of alternative conventional energy sources, if a rational decision is to be made. We need energy to fulfill our aspirations for lifestyle and survival. Environmental impact of some sort is inevitable.

A *third problem* with renewable energy is its *intermittency*. Unlike fossil fuel, the source cannot be controlled to match demand. The energy is not available all the time, and may not even be easy to predict. To match supply to demand, it may be necessary to store energy, or to reschedule our use of energy, or to use a mixture of different energy sources. This consideration in itself increases the cost and the environmental impacts of the energy we ultimately use at our convenience. On the small scale (domestic electricity systems), we can use batteries to store the energy for later use.

In most electricity systems, the energy must be generated at the same rate as it is used. In other words, the generating plant must be large enough to meet the peak power demand on the system. In a renewable energy system, the energy is generated according to the weather rather than on demand. In the absence of storage, a great deal of this energy will be dumped (usually as some sort of useful heat). In order to be large enough to meet peak power demand, the turbine (or whatever) will have to be much larger than the size required to equal the average energy demand.

Capacity factor can be improved by charging batteries during times of low demand and the using battery power to supplement the turbine during periods of higher demand, or when there is no wind or water. By adding battery storage to the system we reduce the amount of generating plant required to meet the electrical load. This comes at a price. Batteries are expensive and need to be replaced every few years. And without battery storage, small wind or hydro power installations would be virtually useless for electricity supply.

2 Wind turbine with Vertical Axis and Helical Rotor Shape

Comparing with the other renewable energy sources, such us of tidal energy, wind energy has a more variable and diffuses energy flux. In order to maximize the benefit of the wind energy, it is very important to be able to describe the variation of wind velocity at given site.

The wind resource depends not only on the wind speed but also on its distribution in the time, as is know “wind frequency distribution”. The unforeseeable irregularity of the wind does not allow to design fluid-dynamically optimized (i.e. working at maximum efficiency) turbines, as this requires constant or slowly and little varying fluid-dynamic conditions at inlet [1].

A thorough understanding the characteristics of the wind regime in which wind the turbine is expected to work is a pre-requisite for the successful planning and implementation of any wind power project. Knowledge of the wind velocity distribution at different time scales and quantum of energy associated with these wind spectra are essential for the proper sizing and sitting of a good wind energy project [3].

In isolated area, with not connection to national network, it can be used to produce electricity with good results a wind turbine with vertical axis helical type (Fig.1).

Fig.1 Wind turbine with vertical axis helical type mounted on a car during experimental tests.

The monoblock rotor helical type with three blades made from fiberglass, is a new conception, patented, and has the next advantages in comparison of wind turbine with horizontal axis [2]:

- simpler construction with good rigidity;
- high reliability
- smaller cost with 20 %;
- higher specific power on the active surface;
- high torque moment at starting;
- self breaking at wind speed bigger than 20 m/s without mechanical components;

- doesn’t need orientation after wind direction;
- can work till win speed of 50 m/s;
- is only one wind turbine which was accepted by the environment agencies, because doesn’t kill the birds;
- doesn’t make noise during the function time;

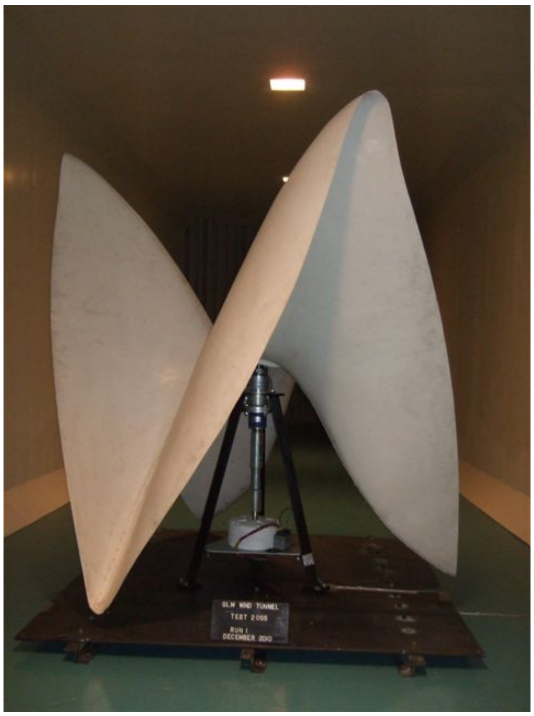

Fig. 2 Helical rotor shape tested in aerodynamic tunnel.

The rotor was mathematically modeled and tested in experimental conditions mounted on a car adapted as a mobile laboratory, where was measured the next parameters:
- wind speed [m/s];
- spindle revolutions [rpm];
- power of generator [W];
- air temperature [^{0}C].

In the scheme below (Fig.3) is presented the main components of a wind turbine, that was used during the experimental tests. Because the rotation of this rotor’s type is maximum 60 rpm, is necessary to use a multiplicator of rotation, which ensures an optim regime in function, for the current generator with permanent magnets [4].
The current generated is threephasic, and it need to use a rectifier to can be accurated measured the current tension at different rotations of spindle.

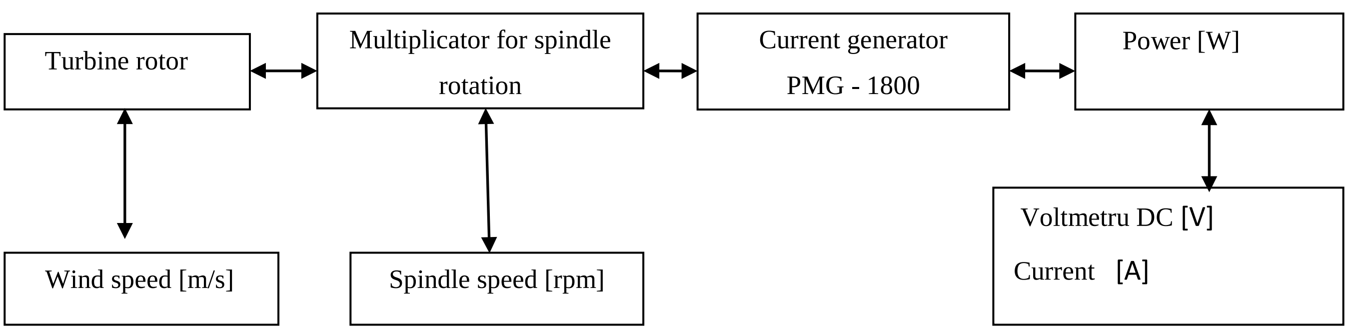

Fig.3 Block scheme of mounting of turbine components for tests.

For the values obtained, wind speed [m/s], spindle speed [rpm] and current tension of generator, is possible to calculate the base parameters of turbine. This base parameter is showed in the variation graph of power [W] according with the wind speed [m/s] [5].

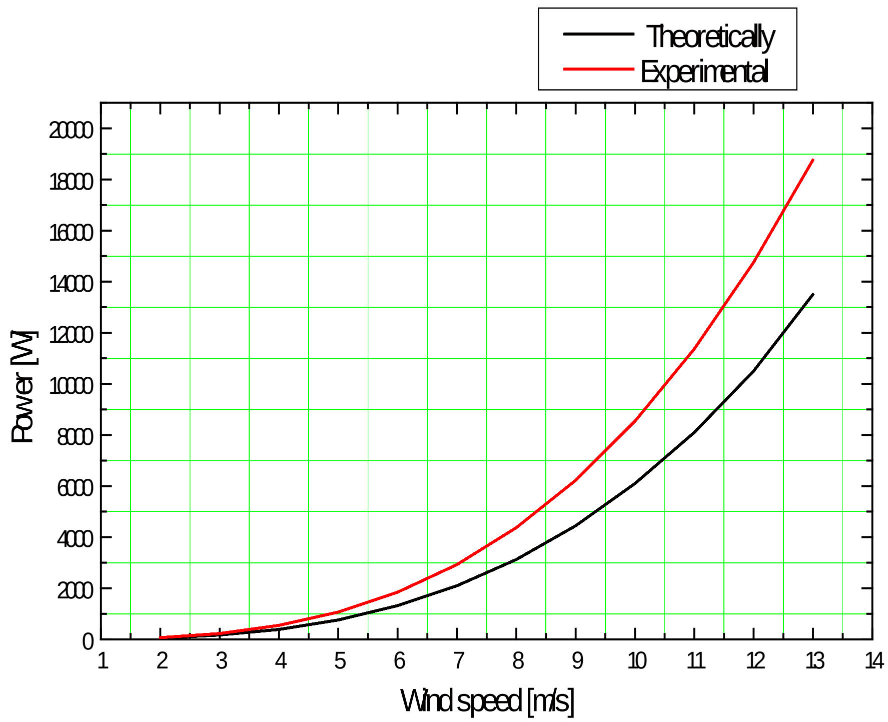

Fig.4 Graphic representation of power variation according with the wind speed in the aerodinamic tunnel

This graph is compared with the values obtained by ther companies which produce wind turbine with vertical axis and same power.

After the experimental tests was obtained the formula of power gives by this wind turbine:

$$P = 0.5 \cdot \rho \cdot Cp \cdot A \cdot w^3 \quad [\mathrm{W}]$$

where:
P – power obtained [W];
ρ- air density -1.225 kg/m^3
Cp – power coefficient;
A – rotor area [4m^2];
W – wind speed [m/s].

The power coefficient obtained was Cp = 0,33 .

A very good technique is to use of probability functions by fitting field data with standard mathematical functions, describing frequency distributions. At this case Weibull distribution can be used to characterize wind regimes (variations) in terms of its probability density and cumulative distribution functions. In wind data analysis Weibull distribution is the most commonly known and widely accepted.

Table 1. Technical characteristics of the wind turbine with vertical axis helical rotor type.

Power	1100 W
Wind speed	- cut-in wind speed: 1,5 m/s - ominal wind speeed: 11,0 m/s - cut-out wind speed: 20 m/s
Blade numbers	1
Rotor diameter	2.0 m
Rotor height	2.0 m
Current generator	PMG 1800
Turbine weight	175 kg

In Fig.5 appears a typical Weibull distribution. Wind speeds of 5,5 m/s are the most coomon used. Speed 5,5 m/s is called the modal value of the distribution. Half of the area in the left of 5,5 m/s shows that the wind will be blowing less than 5,5 m/s, the other half it will be blowing faster than 5,5 m/s. The actually average of the wind speed observations is called mean wind. As it can be seen, the distribution of wind speed is skewed, i.e., it is not symmetrical. Sometimes the wind will have very high speeds, but this situation is happen very rare.

The statistical distribution of the wind speeds varies from place to place, depending upon local climate conditions, the landscape, and shape of the site surface. The Weibull distribution may thus vary, both in its shape and in its main value. The seasonal fluctuation of wind speed constitutes useful element for the calculation of seasonal energy output from a wind generator and quality of adaptation of the energy curve production and the demand.

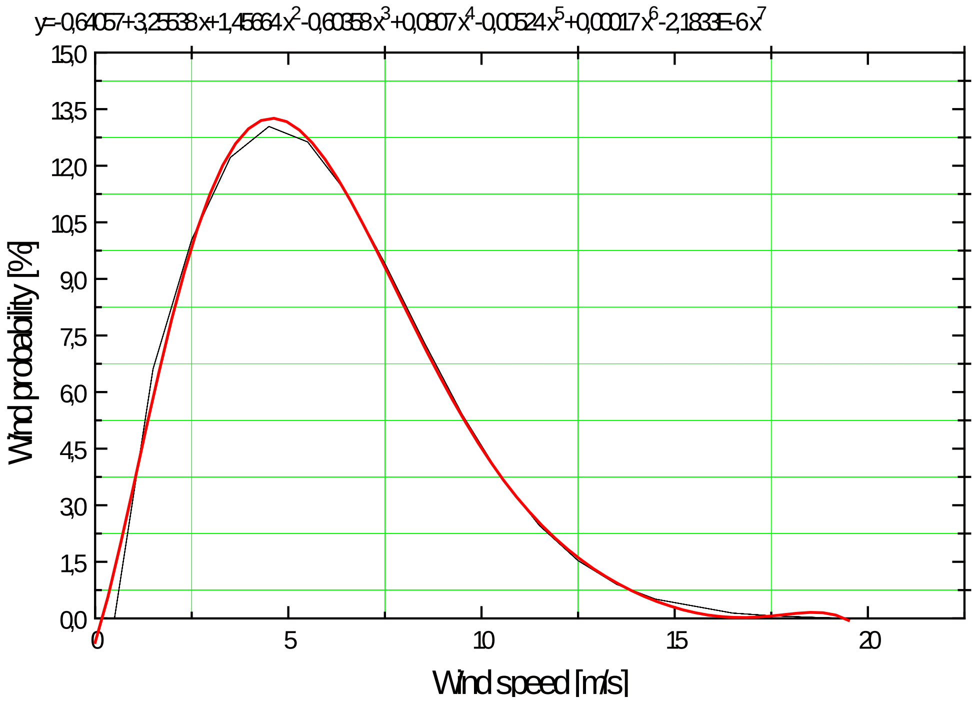

Fig. 5 Weibull probability density distribution for a typical site of tests.

The characteristics of this wind turbine are listed below:
Wind speed (average) for IV class = 6 m/s;
Daily energy output = 6, 5 kWh;
Annual Energy Output = 2378 kWh;
Monthly Energy Output = 198 kWh;
Percent Operating Time = 88 %.

Fig. 6 Wind turbine mounted in Bahamas ireland .

3 Wind turbine with horizontal axis for domestic water supply

Below is presented a wind turbine with horizontal axis which is used to pump water for domestic supply in an area of a small holiday location. It is a place with a few buildings which are located near a river and is needed water for daily requirements.

Wind turbines are classified as vertical or horizontal axis machines depending on the axis of rotation of the rotor. The energy available in the wind is proportional to the cube of the wind speed: if the wind speed is doubled, there is eight times the available power.

Wind turbine has many applications as:

- Stock water – sheep, cattle, horses;
- Domestic applications – household water for drinking, sanitation, and washing;
- Irrigation – for house and vegetable gardens;
- Filling dams, reservoirs, fish ponds, lakes;
- Dewatering wet lands;
- Water for small industry;
- Waste water removal;
- Sewage;
- Remote locations;

The selecting of a wind turbine should be based on the next criteria: wind conditions, source a water supply, water requirements, total pumping head, and governing.

Regarding of wind conditions, the right combination of wind turbine and pump is one which will work easily in light winds (about 10 km/h). This will also depend on the total pumping head [2].

Wind turbine will be useful for pumping water for stock and domestic supplies in isolated rural areas.

For this reason was designed and realized a wind turbine that acts a diaphragm pump and which take water from a river and send it to a tank from where it is sending anytime where is needed.

It can be an economical alternative where:

- Wind conditions are reliable;
- Unattended pumping is required for long periods;
- There is no other viable power source;
- The user requires environmentally clean power;

The principal advantages of using a wind turbine are outlined below:

- run unattended for long periods;
- low maintenance;
- suits isolated locations;
- no energy costs;

Some of their disadvantages are:

- high capital costs;
- intermittent pumping in very light winds;
- requires auxiliary storage;

To select a wind turbine we must taken into consideration some points as a water source, which in our case is a river, the volume of water to be pumped (livestock requirements) and the lift (from water level to top of the tank). Some estimations available wind must be made, preferably from site readings using an anemometer. The wind turbine outlets are normally discharged into an open tank i.e. into the top of the tank.

The wind is a natural resource that is available everywhere. As a general rule the wind blows for between 8 to 10 hours per day, at a speed that is useful for the wind turbine. Table 2–called Beaufort Scale-is used to assess local wind conditions [3].

Table 2. Assessment of local wind conditions.

Force	Name	Definition	Speed range m/s (kph)
0	Calm	Smoke rises vertically	0 (0)
1	Light air	Direction shown by smoke, but not vane	1 (7)
2	Light breeze	Wind felt on face, leaves rustle	2-3 (14-21)
3	Gentle breeze	Leaves, small twigs & flags in motion	4-5 (28-35)
4	Moderate	Raises dust and paper, small branches move	6-8 (42-56)

5	Fresh breeze	Small trees in leaf sway	9-11 (63-57)
6	Strong breeze	Large branches move, wires whistle	11-14 (77-98)
7	Near gale	Whole trees move, walking slightly impeded	14-17 (98-119)
8	Gale	Breaks twigs off trees, walking difficult	17-20 (119-140)
9	Sever gale	Slight structural damage	21-24 (147-168)
10	Storm	Trees uprooted, considerable damage	> 25 (>175)

Table 3 will be used to determine the volume of water that is needed for the wind turbine to pump. After is doing the total requirements is needed to add a safety margin. Usually this margin is between 10 to 50 % and depends on the reliability of the wind resource –a good wind resource will only require a 10 % margin, while a light wind regime will need more (to allow for the days when the wind does not blow) [4].

The idea was to build a wind turbine which is used to pump water for domestic supply necessities in a holiday location where are a number of 10 houses. The holiday place is near to a river and they intend to use the water from the river for their daily needs.

To achieve the needs regarding the domestic supply water was designed and realized a wind turbine with horizontal axis which is presented in Fig.2. The main parts of the wind turbine are: 1- the rotor; 2- the tower or mast made by tubular steel with two sections of pipe coupled together; 3 - the guy wires attached to the tower in three points and with an underground concrete anchor for each set; 4- the diaphragm pump; 5- the concrete base;

To pump the water was chosen a diaphragm pump shown in Fig 8. The pump is acted by a cable (4) that has a reciprocating motion which is received from the rotor mechanism. The rotor mechanism transforms the revolution motion into reciprocating motion through a cam. In a cam operated wind turbine, the lift of the water occurs during more than one-half the cycle. Using a cam that allows for three-quarters of the cycle lifting and one-quarter return, starting torque is reduced by 60 percent. The wind turbine will start in light winds, and if combined with counterbalancing, starting torque is reduced by 72 percent.

The rotor is mage by 12 blades and has a diameter of 1, 5 m. The height of entire turbine is 6 m. The wind turbine is located at 5 m distance from the river whose water we intend to use for domestic needs.

Table 3 Determination of the water volume needed.

Water use	**Estimated daily use (Litres)**
Domestic–drinking (per person)	2
Domestic–hygiene, bathing (per person)	10
Domestic–toilet (per person)	10
Domestic-laundry (per person)	15
Domestic-household cleaning	10
Swimming pool	750
Machinery wash-down	100

A diaphragm pump (5) is a pump that uses a combination of the reciprocating action of a membrane made by rubber and non return check valves to pump water. When the volume of a chamber is increased – the diaphragm moving up- the pressure decreases, and fluid is drawn into the chamber. When the chamber pressure increases from decreased volume – the diaphragm moving down- the fluid previously drawn in is forced out. After that, the diaphragm is moving up again draws fluid into the chamber, completing the cycle.

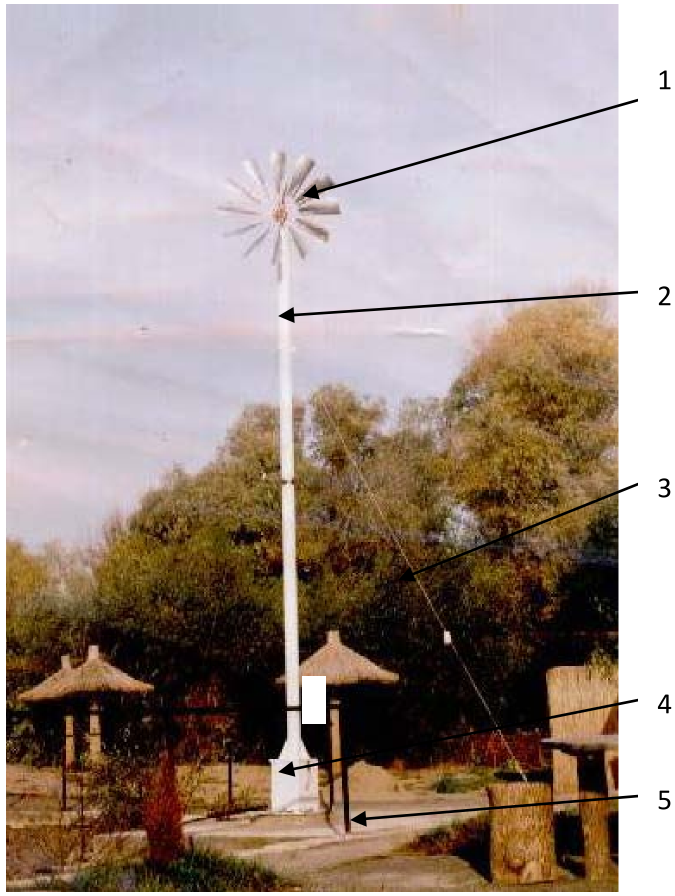

Fig.7 A wind turbine with horizontal axis to pump water.

The entire perimeter of the diaphragm is tightly held and sealed in place between the side of the displacement chamber and a flange, which is tightly bolted to the chamber. Each displacement chamber has two valves, usually spring-loaded ball valves made from the same material as the diaphragm. One of the valves admits the water being pumped to the diaphragm chamber, and the other allows the material to exit the diaphragm chamber. It is a driving mechanism that flexes the diaphragm in and out of the chamber to suction in and force out the water. The water is taken from the river through the device 7 and is sending to the water tank by the flexible pipe 3. The body of the pump 7 is connected to the tower 1 by the plate 2 by a bolt and bush-bearing which helps when the mast is erected in position.

The energy captured by the rotor is proportional to the square of the rotor diameter and the cube of the wind speed. The potential output of a wind turbine is given by this equation [5]:

$$P = 0{,}002 \cdot D^2 \cdot V^3 \qquad (1)$$

where:

P = power in watts;

D = rotor diameter in meters;

V = wind speed in kilometers per hour.

If we expect to have an average wind speed between 3-7 m/s then the wind turbine will give a power between 0,12 -1,54 W which will be enough to start the water pump working. But in the site where the wind turbine is located the wind speeds can have sometimes more than 7 m/s which ensure a good supply of energy for water pump. For the time when the wind doesn’t blow in the site is a tank where the water is stored and can supply enough water for domestic needs.

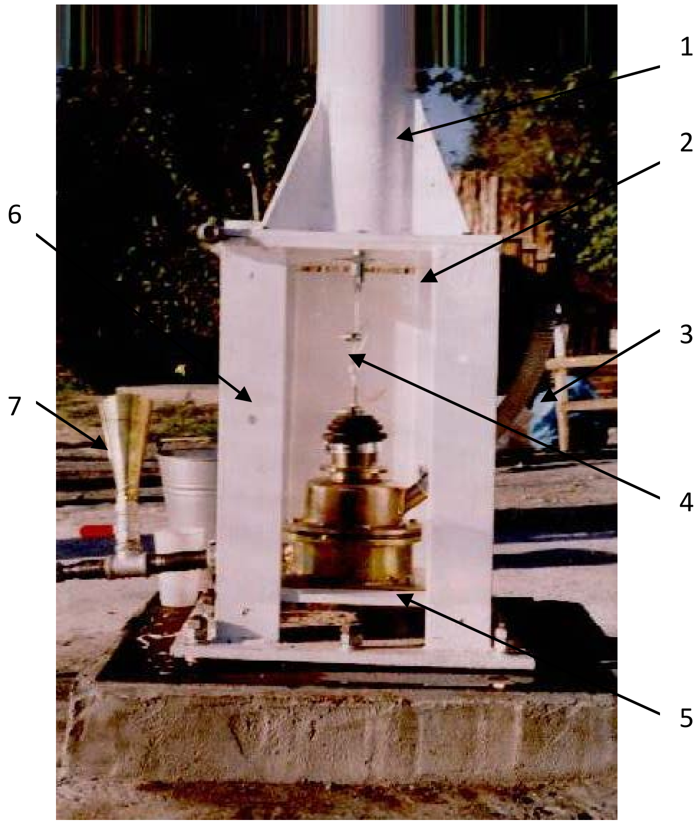

Fig.8 Diaphragm pump used to pump water.

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For the time when the wind doesn't blow in the site is a tank where the water is stored and can supply enough water for domestic needs.

The renewable energy sources have clear benefits that distinguish them from fossil fuels. They are diverse: renewable energy sources can be exploited in more ways and in more places than fossil fuels. They are environment – friendly origin, being known as "green electricity": either they do not lead to greenhouse gas emissions, as in wind and solar energy production.

That is way we use the wind energy to pump water in a location that is remote from electricity grid and that is unattended for long periods.

4 Preparation of domestic hot water in a thermal station using solar collectors

Below is presented a study and an experimental achievements an installation to prepare domestic warm water with solar panels in a area of block of flats in the town Brasov. By implementing this system on the roof of a thermal station, was reduced the gas consumption with 30 %.

Fig.9 Thermal station ASTRA Brasov before installing the solar panels.

The solar photovoltaic energy systems generate electricity pollution –free and can easily be installed on the roof of residential as well on the wall of commercial buildings as grid-connected PV application. In addition to grid-connected rooftop PV systems, solar photovoltaic energy offers a solution for supplying electricity to remote located communities and facilities, those not accessible by electricity companies.

The design of a photovoltaic system (or PV-Generator) relies on a careful assessment of solar radiation at a particular site. The basic measurements that are necessary they are [6]:

Irradiance which is the measure of the power density of sunlight is measured in W/m^2. The Irradiance is thus an instantaneous quantity. The solar constant for earth, is the irradiance received by the earth from the sun at the top of the atmosphere, and is equal to 1367 W/m^2. After passing throw the atmosphere, the irradiance is reduced to approximately 1000 W/m^2, and has a modified spectral content due to the atmospheric absorption.

Irradiation is the measure of energy density of sunlight and is measured in kWh/m^2. Since energy power integrated over time, irradiation is the integral of irradiance. Normally, the time frame for integration is one day, which of course means during daylight hours.

The total radiation in atmosphere of ground consisting of three components and is called global radiation. The three components are [5]:

- direct or beam radiation, which is the radiation that is not reflected or scattered and reaches the surface directly in line from solar disc;
- diffuse radiation, which is the scattered radiation which reaches the ground;
- ground reflected part of the global solar radiation.

Since a typical photovoltaic cell produces less than 2 watt at approximately 0, 5 Volt dc, cells must be connected in series-parallel configuration to produce

enough power for high power applications. Cells are configured into modules, modules are connected as arrays.
The purpose of this project is to realize an installation for preparation domestic hot water using solar energy in a thermal station in a block of flats area (Fig.9). Using this experience will be also possible to extend this installation to other thermal points that fulfill the required conditions. It was estimated that by implementation of this kind of solar installation to a thermal station is making a reduction of gas consumption of 20-35 %.
In Fig.10 is shown a scheme of function principle of the main elements for the installation to obtain domestic hot water using solar energy.
In the primary circuit of solar collectors is an antifreeze liquid which is sending by pumping system to a heat exchanger.
Water from the network is passing through the secondary circuit of heat exchanger, where it take the thermal energy received from the solar collectors that are mounted on the roof of thermal station. In this way the water is preheated to a temperature of $\Delta t = 10\text{-}45^0$ C.
The water from the network used to prepare domestic hot water by thermal station, will enter through the heat exchanger that exist with a warm water with this temperature Δt, according to the intensity of solar energy [4].
The installation start to work when the temperature of the water given by solar collectors is greater with 5^0 C than the temperature of the water received from the network.

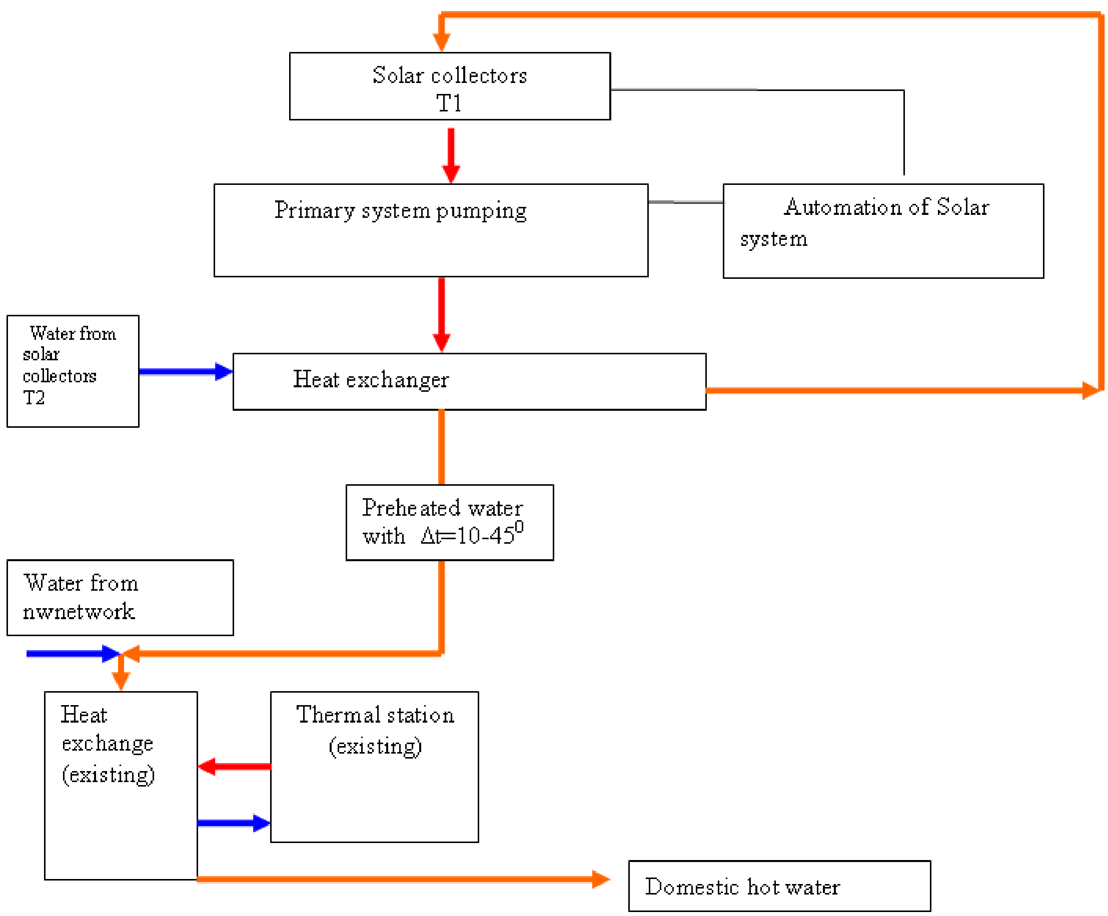

Fig.11 Scheme of installation to make domestic hot water using solar energy.

When the temperature from solar collectors is smaller than temperature of network water ($T_1<T_2$), the automation installation will give a signal to stop the pump. In these conditions, the work of solar installation will be in automatic state (Fig.12).

It is good to mention that during the summer time even at solar diffuse radiation, the installation work in good condition taking from the solar energy a value of 50% of total energy received that will preheat the water from the network.

In the summer time it is possible to obtain hot water at temperature of 50-55^0 C, only with solar diffuse radiation.

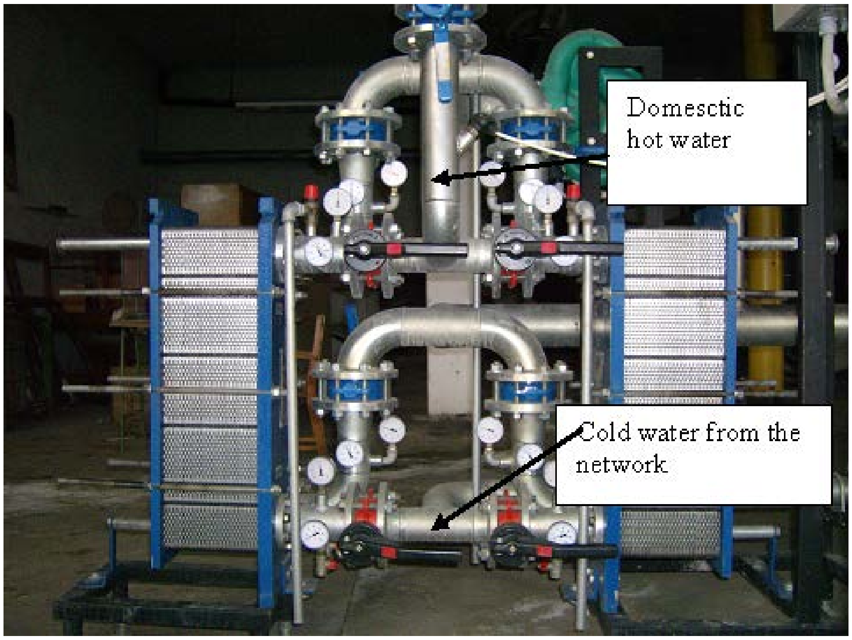

Fig.12 Heat exchanger that exist in thermal station.

Fig.13 Zone of connection with the piping from the solar collectors.

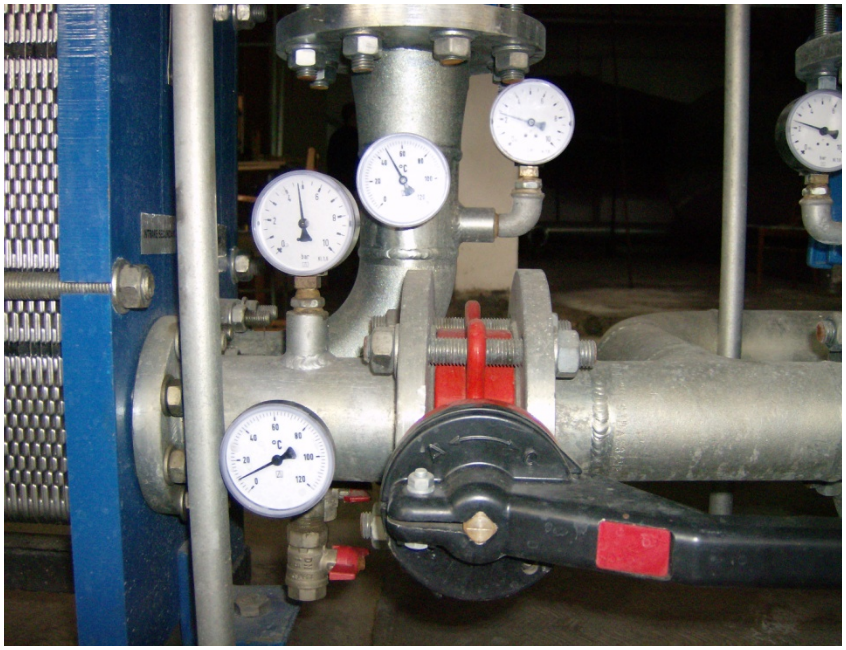

Fig.14 Inlet parameters of water in the existing heat exchanger.

Fig.15 Solar collectors mounted on the roof of thermal station.

In Fig.15 is shown the way of mounting of solar collectors on the roof of thermal station with concrete plate that work in good conditions even at wind speed of 100 km/h.

4.1 Energetic efficiency

Evaluation of the energy saving obtained after implementation of the project

From our studies and literature we will obtain the next savings by using 100 solar collectors on the roof of thermal station:

E = 219,97 MWh/year;

E = 48,8 tep/year; (tep = petroleum tons equivalent per year)

In every year is obtained for one thermal station a saving of :

E = 14574 Euro.

The total value of investment V_i

V_i = 94605 Euro

Duration to recoup the investment D_{re} [1]

$$D_{re} = \frac{V_i}{E} = 6{,}3\ years$$

The solar power potential in the site Q_{rre}

The power in $kWh/m^2/day$ received from the sun in the site where are mounted solar collectors, with the data obtained from the satelite are:

6,1 $kWh/m^2/day$ during the summer time;
1,5 $kWh/m^2/day$ during the winter time;
Q_{rre} = 6,51 $tep/m^2/year$

The quantity of natural fuel saved by using solar collectors E_{rre}

By mounting to the thermal station ASTRA Brasov of solar collectrors is obtained a saving of methan gas E_{rre}:

E_{rre} = 21997 Nmc/year.

By using solar collectors are nor emmited in atmosphere a quantity of 2479 Nmc CO_2/year and the efficiecy during the summer time is of 30 %.

By this project that was implemented in the thermal station for producing domestic hot water in dwillings was demonstrated the efficiency of mounting the solar panels even in the areas where the intensity of solar radiation is smaller. For this purpose was used the new soplar collectors with vaccum which greater performances.

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