2011

COLLEGIUM GEOGRAPHICUM 8.

SPECIAL EDITION

PROCEEDINGS BOOK

ENERGIA TRANSYLVANIAE

INTERNATIONAL CONFERENCE ON SOLAR, WIND AND BIOENERGY held on 14 May 2011 in Cluj-Napoca, Romania

Ábel Publishing House

Collegium Geographicum

Cholnoky Jenő Geographic Society
400080 Cluj-Napoca, Baba Novac street no. 23/2, Romania
www.cholnoky.ro

The Proceedengs Book is published in the special edition of Collegium Geographicum with a sponsorship of Bethlen Gábor Fund.
The autors take resposibility for the content of the article.

ISSN 2065 - 3859

Ábel Publishing House
400304 Cluj-Napoca, Eremia Grigorescu street no. 35
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Preface

Growing energy demand of our world needs proper management of energy on both global and regional scale. In order to maintain the security of energy supply in a sustainable environment all renewable energy sources must be actively utilized in our daily life.

The energy policy as the main driving force of renewable energy industry is to be harmonized on the regional, national and international level, with special focus on Southeastern Europe. In the same time the linkage between different sectors dealing with renewable energy should be enhanced.

Determined by the purpose of playing key role in renewable energy use promotion, Babes-Bolyai University Cluj-Napoca, Faculty of Geography in collaboration with Cholnoky Jenő Geographical Society get the idea to organize the ENERGIA TRANSYLVANIAE INTERNATIONAL CONFERENCE ON SOLAR, WIND AND BIOENERGY to provide a platform for researchers, engineers, developers as well as industrial professionals to present and share their research, results and experiences in this area.

The main objective of the conference is to share knowledge regarding renewable energy researches and implementations, to highlight the actual state of renewable energy use. Bringing together those who are interested in renewable energy sources from different sectors (scientific, political, social, private) such as universities, research institutes, governmental and non-governmental organizations, economic operators an multidisciplinary discussions can be induced focusing on renewable energy research and applications. In the same time the conference calls the attention to the role of renewable energy industry in the regional development.

We intend to create a favorable atmosphere for sharing new information and to enhance further collaborations.

We wish successful conference!

The Organizing Committee

Contents

Building Integrated Photovoltaic System (BIPV) in Romania

Laurentiu FARA[1], Andrei GALBEAZA MORARU[1]*

[1]Polytechnic University of Bucharest

The paper presents a demo BIPV system developed at Polytechnic University of Bucharest within a research national project called PASOR (2007–2010). The system consists in 6 PV panels of two kinds (three with Pmax=120 W and three with Pmax=84 W), a high efficiency Sunny Boy 700 inverter which uses a MOSFET bridge to convert DC to AC in high frequency and a monitoring equipment, Sunny Boy Control Plus, which offers many storage and data processing facilities. For a better evaluation of the panel's efficiency rate and its variation, a LaCrosse WS2500 Weather Station was installed for measuring the meteorological parameters (wind speed and direction, atmospheric pressure, precipitation quantity, solar radiation, temperature and humidity). The specific software installed on the renerg.pub.ro server allows us to combine the data, and analyze the influence that the meteorological factors have over the BIPV efficiency.

Keywords: building integrated photovoltaic (BIPV), meteorological parameters, monitoring system

Introduction

PV integrated in buildings mean new ways to improve the performance of a building using an attractive design. While standard PV solutions are often used in solar farms or residential applications, BIPV provide many new possibilities for architects to incorporate solar technology into buildings [1,2]; PV systems and architecture can now be combined in a harmonious blend of design, ecology and energy saving.

The photovoltaic modules that are integrated into buildings can create a lot of new possibilities. A wide variety of elegant designs, colours and optoelectronic structures of cells, glass and profiles can create a modern approach of the architectural design. It's enough to deliver an energy efficient design that is both innovative and original, using a set of new architectural standards that combine elegance with functionality. PV modules can be made according the size and the customer requirements.

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A selection of cells can be adjusted to provide the project's specific design which takes into account: transparency, lighting control, design module, shading, and the appropriate size. Using more than 40% of the world's electricity, buildings can be considered as the biggest energy consumers.

Today, architects, consultants, developers, contractors and investors are sure that their choice of renewable energy produced in a responsible and environmentally friendly way, along with their passive solar energy use in buildings is the right one.

In order to protect the Earth, the world governments are increasing their efforts to reduce CO^2 emissions by encouraging the use of renewable energy sources and substitution of fossil sources. The EU has proposed to drastically reduce the CO^2 emissions target and having approximately 20% of energy from RES by 2020. Support is done through research, in order to widespread the use of photovoltaic and solar or thermal energy.

Today, many governments have a generous offer in order to implement the BIPV technology.

Design of a BIPV system at Polytechnic University of Bucharest

During the national research project PASOR (Promotion of Architectural Solutions for Building Integrated Photovoltaic Systems) development, a PV window has been installed at the Polytechnic University of Bucharest, Faculty of Applied Sciences, in the NANO-PV laboratory. Fig.1 shows the diagram of the external structure of the BIPV installation in the NANO-PV laboratory windows [3].

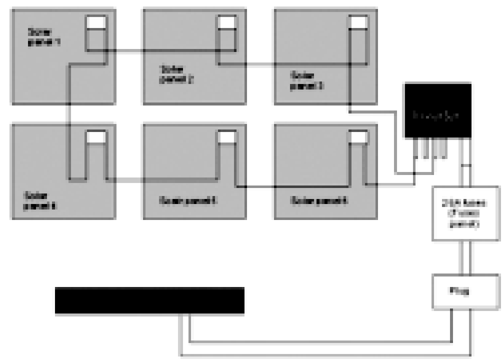

Figure 1. BIPV system structure

For the installation two types of PV panels were chosen. There were installed three panels type 2 and three panels type 2. Table 1. shows the characteristics of the selected photovoltaic panels

On the basis of the order made in November 2007 – January 2008 the required photovoltaic modules and the rest of the equipment which was necessary to implement the BIPV system have been delivered (inverter, monitoring and storage systems). In July 2008 the photovoltaic panels were installed on the laboratory BN 119-bis window.

The inverter is a Sunny Boy SB700 model which operates a high conversion efficiency using a MOSFET bridge to convert DC to AC cells in high frequency (16 kHz). It can support up to ten solar pane with a jumper that can be set depending on the tension generated by the panels.

The monitoring equipment, Sunny Boy Control Plus, offers many facilities for storage (up to one year of measurements) and data processing from the inverter. Sunny Boy Control Plus can display the total energy in the network, and the energy that is generated by the solar panels. It can also display the inverter's operating parameters in real time.

Table 1. Characteristic of photovoltaic panels

Feature	Type1	Type2
Dimension	1550 x 800x 6 mm	1050 x 800 x 6 mm
Weight	14 kg	9 kg
Number of cells in series	50	35
Cell size	12,7 cm	12,7 cm
Under normar operating temperature (800)	47 °C	47 °C
Electrical		
Maximum power	120 W ± 5%	85 W ± 5%
Current al maximum power	4,31 A	4,31 A
Voltage at maximum power	27,5 V	19,25 V
Design		
Cell type	Crystalline SI, textured and xovered with an anti-reflector	
Contacts	Redundant contact to ensure high reliability	
Rolling	Ethyline-vinyl acetate	
Front	Reinforced galss, with an improved light (4 mm)	
Rear	Tedlar, multi-layer	
Framework	Aluminuim	
Connection points	IP 65	
Cercification	CE	

Meteorological parameters measurement station

In order to analyze the BIPV system performances depending on the meteorological parameters, a weather station has been installed to monitor the evolution of the system.

The center for the measuring of meteorological parameters is located in the BN 119 Bis laboratory of the Faculty of Applied Sciences, Department of Physics II. Construction and installation works have been carried out in May-June 2008.

Hardware structure

The station that is used to measure the meteorological parameters is a commercial, LaCrosse WS2500 Weather Station. The basic package contains six external sensors for wind (speed and direction), temperature, humidity, atmospheric pressure, solar radiation and precipitation and two more internal sensors that measure temperature and humidity in the room where the weather station is installed. Data is read from the sensors every 5 minutes. The sensors are installed on an outside terrace, at a distance of about 5 m from the laboratory. The wind sensor is installed on the top of a mast so that the presence of the wall behind him doesn't influence in any way the measurements. The device that receives, processes and stores data from the meteorological sensors is shown in Fig. 2.

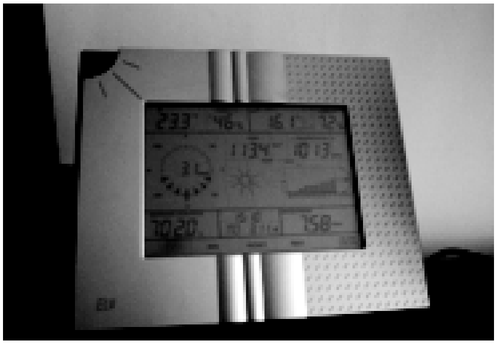

Fig. 2. The weather parameters monitoring system

Sensors for measuring meteorological parameters

The internal temperature sensor has a measuring range from –30 °C to +70 °C with an accuracy of 0.1 °C. The data from this sensor is read every three minutes. The second internal sensor, which measures the humidity, has a range of 1–99% and 1 % resolution.

The external temperature sensor has the same parameters as the internal one, but the weather station, depending on the sensor, can display a tendency to increase or decrease in temperature.

The atmospheric pressure measurements are obtained by using another external sensor that allows a range of 800–1100 kPa. Using this sensor, the weather station can display both the relative and absolute atmospheric pressure. You also can set the sensitivity level for the measurements.

For the measuring of the wind direction and speed we use a sensor that allows the measurement of speeds between 0–200 km/h and covering 360° for direction .The rain sensor has a measuring range between 0–999.9 mm for 1–24 hours and 0–2499.9 mm for 8 days. The provided resolution is 0.5 mm.

The solar radiation flux and the sunshine duration are recorded by another sensor.

The measurement units for the solar radiation flow are klux and lux and the sunshine duration is measured in hours.

BIPV demo system

The hardware structure

The basic components are a weather monitoring station and a data logger, plus two computers for data acquisition and a Web server used for processing and presenting data in a format that can be understood by the user.

In terms of communication, the connection between the monitoring devices and the computers that download data is done via standard RS232 serial communication

The connection between the inverter and data logger is done through the power grid, frequency 100 kHz.

The connection between the computers and the server is done via Ethernet at speeds of 1 Gb/s, the two computers are part of a cluster used in numerical simulations.

Once new data are available, computers send data to a server that plugs them into a database. The hardware structure of the BIPV system is presented on Fig. 3.

Software structure

One of the notable things is the fact that we used almost entirely open-source software to achieve the monitoring system, the only exception being the software for communication - data logger that has been provided by the manufacturer of equipment (SMA America). This approach provided us with a zero cost for the software used in the monitoring system.

For data storage we use a MySQL database distributed on three computers for redundancy, any change made by one computer in the database is replicated by the other two computers.

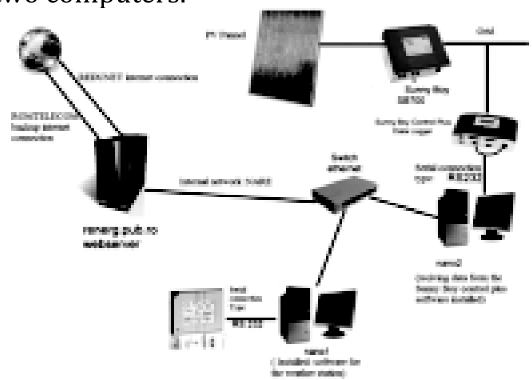

Fig. 3. Hardware structure of the BIPV demo system

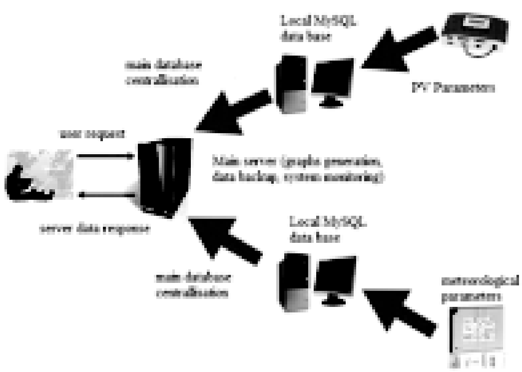

Fig. 4. The operating principle of the monitoring system

The database's structure is created so that queries and data processing take place as soon as possible. Thus, we must create a separate table with PV parameters (named: parameters _PV_ [month] _ [year]) and meteorological parameters (named meteo_parameter [month] _ [year]) measured for each month.

Graphs are automatically generated at the user's request through a PHP script that uses the GDI library of image processing. The operating principle of the monitoring system is shown in Fig. 4.

Experimental results and interpretation

System performance- the system generates a peak power between 07:00 and 12:00, during the other time slot it is partially shaded. On Fig. 5. is an example of the evolution of the PV system during a summer day [4].

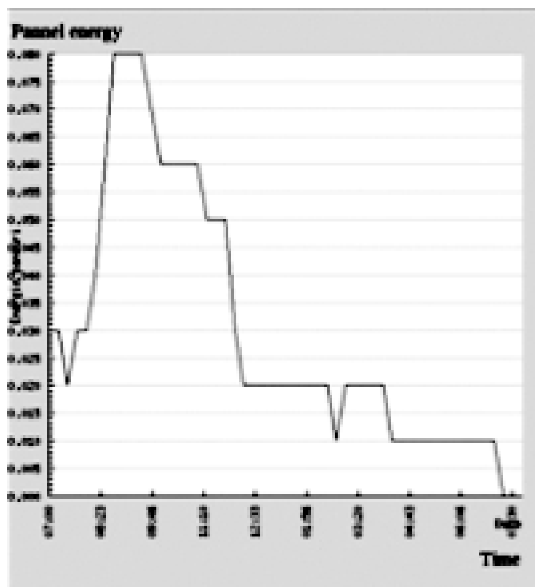

Fig. 5. BIPV system evolution on 07/06/2009

The system's performance is strongly influenced by solar radiation and outside temperature. This can be seen on Fig. 6. where the chart represents the system's energy depending on solar radiation.

Currently, the system records an operational duration of 504 days and the total power generated was 73.11 kWh. The evolution of the energy generated is presented on Fig. 7.

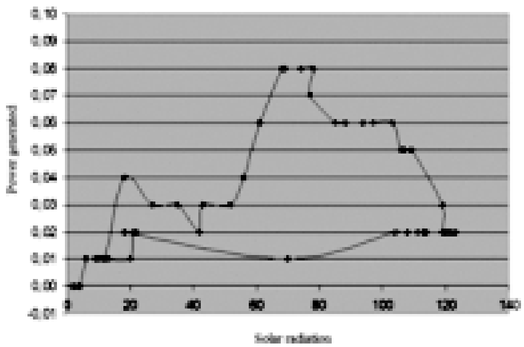

Fig. 6. The Evolution of the energy generated by solar panels depending on the solar radiation measured by the weather station on 06/07/2009

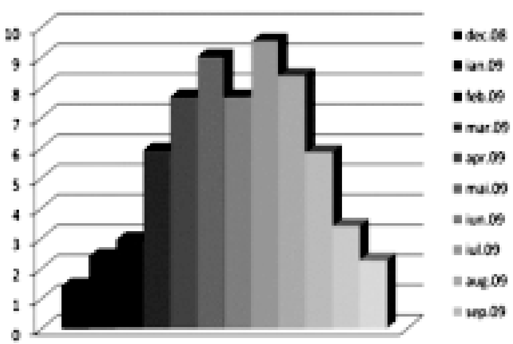

Fig. 7. Power cut in the network by the BIPV system at the Polytechnic University of Bucharest in the period December 2008–November 2009

Conclusions

The main contributions obtained in this paper are as follows:

The BIPV window designed and built at Polytechnic University of Bucharest in 2008 was the first BIPV system developed in Romania.

All data from the Sunny Boy Control Plus monitoring equipment is stored to a MySQL data base on the "nano2" server. The data from the Weather Station Monitoring system is stored also in a MySQL data base on the "nano1" server. The two combine through a TCP/IP connection in the main server, renerg.pub.ro and create a new data base with centralized data from the two systems.

This BIPV system represents a very good education platform for renewable energy course dedicated to students from the final year of the Faculty of Applied Sciences, Polytechnic University of Bucharest as well as for students who are following at Master Division on Photonics and Advanced Materials at the same faculty.

The system could constitute a good start for future development of BIPV systems in Romania.

Acknowledgements – This work is based on a research national project called PASOR, within the partnership programme and was supported by the Romanian Ministry of Scientific Research in the period 2007–2010.

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Collegium Geographicum 8. Special Edition, 2011

Modeling, Simulation and Experimental Results for a BIPV System

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A BIPV system model has been built and simulated using the PVSYST software package. Based on the obtained data, the BIPV system from Polytechnic University of Bucharest has been implemented. Using Grad program the solar radiation has been simulated on a sample period, the same used for gathering experimental data from the implemented system. There were discussed the experimental results in comparison with the simulated ones.

Keywords: BIPV, solar radiation, simulation, dimensioning

Introduction

Four Universities from Romania (West University Timisoara, University "POLITEHNICA" Bucharest, University "POLITEHNICA" Timisoara, University of Architecture and Urbanism "Ion Mincu") together with one research institute (SC. IPA.SA) have assessed the possibility of introducing new architectural concepts on the Romanian market which include active solar systems (photovoltaic generators) or passive solar systems (lighting systems). To achieve this goal, the following quantifiable stages where necessary:

- Surveys, research and solutions regarding the solar architecture in Romania.
- Surveys, measurements and technical solutions for the pilot installations with integrated photovoltaic systems;
- Construction of three demonstration pilot photovoltaic installations monitored at the West University Timisoara (UVT) and at the University of Architecture and Urban Planning "Ion Mincu" (UAUIM), Bucharest;
- Experiments, tests and outcome analysis.
- Large-scale dissemination

The major purpose of PASOR (Promotion of architectural solutions for building-integrat-

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ed photovoltaic systems) project is to demonstrate the efficiency of integrating various PV elements in buildings, to test them and to make them known so that they can be used on a large scale [1].

One of the three pilot-actions of the project was developed at the Polytechnic University of Bucharest. A BIPV (Building Integrated Photovoltaic) system was developed in an experimental Laboratory of Faculty of Applied Sciences and was connected to the grid. For better monitoring of the system's performances a weather-monitoring station was installed so the evolution of the PV parameters can be compared to the metrological ones.

The purpose of the present paper is to build and simulate a model based on the characteristics available at Polytechnic University of Bucharest and to compare the results with the experimental results obtained after installation.

Dimensioning the BIPV system at Polytechnic University of Bucharest

Before the installation of the BIPV system at Polytechnic University of Bucharest, a large number of surveys and computed system models have been achieved.

Different simulation and sizing software as HOMER, RET Screen or PVSYST have been used to obtain optimum results. These modeling software use different databases for irradiance (direct, global and diffuse) values, different libraries for PV modules and inverters manufacturers and different algorithms for losses assessment.

In the following paragraph the PVSYST software will be analyzed, as well as its simulation results.

PVSYST – general analysis

PVSYST is a software package for the sizing, simulation and data analysis of complete PV systems. It can be used to easily design and compare various systems, using several project levels. The software is designed by the Institute of Environmental Sciences (ISE) at the University of Geneva [2].

The program offers the possibility to model grid connected, stand alone, pumping or DC grid PV systems. The defining parameters used by PVSYST for simulation are:

- Project general data (which include general data about the position of the future installation, albedo data, and other site-dependent design parameters)
- Orientation of the PV Modules (tilt and azimuth)
- Horizon line drawing
- System data (PV module, inverter, number of modules and strings selection)
- Module layout (customized design of PV modules)

After the simulation, the program offers a full-report on the constructed model as well as improvement options as different inverter choice a.o. A model designed in PVSYST based on the characteristics of the BIPV system at Polytechnic University of Bucharest is discussed in the following section.

Designing the model in PVSYST

The project discussed is based on a grid connected BIPV system model. For the geographical and meteorological parameters, Bucharest Synthetic Hourly data for Meteonorm '97 Site have been chosen from the supplied library. The project's albedo parameters as well as the site – dependent parameters are presented in Fig. 1.

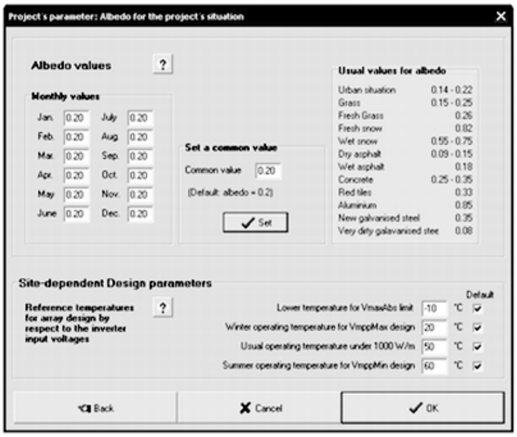

Fig. 1. Albedo parameters of the Project

The tilt value is set to 90˚ (PV window in vertical position) and the azimuth set for the east orientation of the panel. The program generates an optimization chart as shown in Fig. 2.

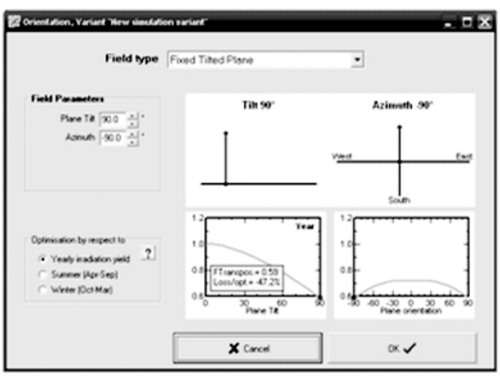

Fig. 2. Panel orientation

Further on, the grid system is defined; the PV modules and the inverter are chosen as well as the number of modules and strings, based on the sizing conditions (available area), and planned power (600 Wp) as shown in Fig. 3.

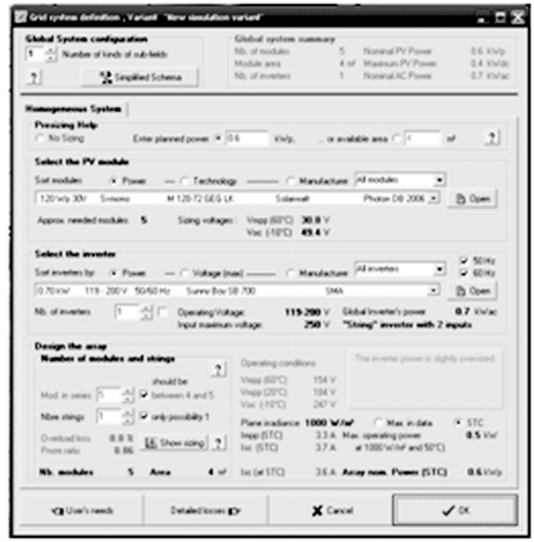

Fig. 3. Grid system definition

After input of all parameters and conditions, the model has been simulated. The program offers a simulation report which contains all used parameters and results of the created model.

Simulation results

The system has been simulated under the following conditions and parameters (Table 1.)

The simulation returned the information shows us that the simulated model produces 351 kWk/year with a performance ratio (PR) of 73.5 % and a specific production of 584 kWh/kWp/year. In Table 1 are shown the main simulation parameters (geographical site, panel tilt, azimuth), the PV Array characteristics (number of modules, operating characteristics, inverter data) and the loss factors (thermal loss, wiring ohmic loss, module quality loss a.o)

A detailed balance with the main results is shown in Table 2.

Legends:

GlobHor – Horizontal global irradiation

Table 1. Simulation parameters and conditions

PVSYST V5.4				22/04/11
	Grid-Connected System: Simulation parameters			
Project :	Grid-Connected Project at Bucuresti			
Geographical Site	Bucuresti		Country	Romania
Situation	Latitude	44.5°N	Longitude	26.1 °E
Time defined as	Legal Time	Time zone UT+2	Altitude	88 m
	Albedo	0.20		
Meteo data :	Bucuresti, Synthetic Hourly data			
Simulation variant :	New simulation variant			
	Simulation date	22/04/11 08h10		
Simulation parameters				
Collector Plane Orientation	Tilt	90°	Azimuth	-90°
Horizon	Free Horizon			
Near Shadings	No Shadings			
PV Array Characteristics				
PV module	Si-mono Model	M 120-72 GEG LK		
	Manufacturer	Solarwatt		
Number of PV modules	In series	5 modules	In parallel	1 strings
Total number of PV modules	Nb. modules	5 Unit Nom. Power		120 Wp
Array global power	Nominal (STC)	600 Wp At operating cond.		539 Wp
Array operating characteristics (50°C) U mpp		161 V	I mpp	3.3 A
Total area	Module area	4.4 m²		
Inverter	Model	Sunny Boy SB 700		
	Manufacturer	SMA		
Characteristics	Operating Voltage	119-200 V Unit Nom. Power		0.70 kW AC
PV Array loss factors				
Thermal Loss factor	Uc (const)	20.0 W/m²K	Uv(wind)	0.0
=> Nominal Oper. Coll. Temp. (G=800 W/m², Tamb=20°C, Wind velocity = 1m/s.) NOCT				56 °C
Wiring Ohmic Loss	Global array res.	809 mOhm	Loss Fraction	1.5 % at STC
Module Quality Loss			Loss Fraction	1.5%
Module Mismatch Losses			Loss Fraction	2.0% at MPP
Incidence effect, ASHRAE parametrization IAM =		1 - bo (1/cos i-1)	bo Parameter	0.05
User's needs:	Unlimited load (grid)			

Table 2. Balances and main results of the simulation

	GlobHor kWh/m²	TAmb °C	Globlnc kWh/m²	GlobEff kWh/m²	EArray kWh	E_Grid kWh	EffArrR %	EffSysR %
January	41.0	-1.00	30.2	28.8	15.68	13.22	11.76	9.91
February	55.0	0.10	37.2	35.6	19.44	16.72	11.81	10.16
March	89.0	5.60	53.8	51.6	27.79	24.27	11.68	10.16
April	134.0	11.11	77.5	74.4	39.47	35.05	11.51	10.23
May	168.0	16.70	96.2	92.4	47.98	42.81	11.28	10.06
June	192.0	20.00	106.4	102.2	52.46	47.04	11.15	9.99
July	196.0	22.20	112.1	107.8	54.57	48.98	11.01	9.89
August	175.0	21.70	101.2	97.3	49.52	44.36	11.07	9.92
September	122.0	17.90	76.7	73.6	37.91	33.72	11.18	9.94
October	84.0	11.80	54.4	51.8	27.32	23.92	11.37	9.95
November	42.0	4.50	29.9	28.4	15.15	12.71	11.45	9.60
December	29.0	0.70	19.8	18.7	9.94	7.95	11.38	9.09
Year	1327.0	11.01	795.4	762.6	350.64	275.17	11.30	9.97

TAmb Ambient Temperature
Globlnc Global incident in coll. plane
GlobEff Effective Global, corr. for 1 AM and shadings
EArray – Effective energy at the output of the array
E_Grid – Energy injected into grid
EffArrR – Effic. Eout array/rough area
EffSysR – Effic. Eout system/rough area

Detailed information about energy loss is also offered. In Fig. 4. is presented the loss diagram for a whole year. The diagram comprises all loses caused by the conversion efficiency, as well as module and inverter losses.

Fig. 4. Loss diagram

Building the BIPV system at Polytechnic University of Bucharest

In conformity with the simulated results, there were chosen two types of PV panels, with the following characteristics:

Table 3. Cell characteristics

Characteristics	Type A	Type B
Dimensions	1550 x 800 x 6 mm	1050 x 800 x 6 mm
Mass	14 kg	9 kg
Number of cells	50	35
Cell dimension	12,7 cm	12,7 cm
Normal functioning temperature (800 W/m^2, 20° C, AM 1.5, 1m/s)	47° C	47° C
Maximum power	120W ± 5%	85W ± 5%
Current at maximum power	4,31 A	4,31 A
Maximum voltage	27,5 V	19,25 V
Cell type	Si mono with anti-reflecting foil	
Contacts	Redundant contacts for high efficiency	
Lamination	Ethylene-vinyl Acetate	
Front	Thicken glass (4mm)	
Back	Multilayered transparent Tedlar	
Frame	Aluminum	
Connection points	IP 65	
Certification	CE	

The installed system consists in 6 PV panels, one inverter and one data logger. There are two kinds of panels used of 85 and 120 W each. The total power supplied by the panels is 615 W. The Inverter is a Sunny Boy SB 700 model of 700 VA. It uses a MOSFET bridge to convert DC into AC at high frequency (16 kHz) and can support up to 10 PV panels and has a jumper which can be set depending on the power generated. The current supplied to the grid is perfectly sinusoidal [5].

The Data Logger is a Sunny Boy Control Plus Model which can register up to one year of PV parameters (total power generated by the PV panels, total power supplied to the grid per day, instant energy produced, generated voltage and so on). It connects to a computer trough a null-modem serial cable RS232 and can take-over information from other inverters connected to the grid, identifying them by their serial number [3].

Simulated results for solar radiation

In order to estimate the system's performances, we have simulated the global, direct and diffuse irradiation for a sample-period between 01.10.2010 and 31.11.2101.

The program used for irradiance simulation is Grad, which is a scientific model of the solar radiation programmed in Java language. Using this program, we can simulate the global radiation with its components (direct, diffuse and reflected radiation) as well as radiation for a clear sky or real meteorological conditions (certain meteorological conditions are required) [4].

As input data, the program receives a file in which are defined the main characteristics of the target area (longitude, latitude, aspect, elevation and slope). For the test area at the Faculty of applied Sciences, the file has the following content:

„Longitude", „Latitude", „Elevation", „Slope", „Aspect"

1.6, 50.9, 300, 0, 0

1.6, 50.9, 300, 10, 0

1.6, 50.9, 300, 10, 45

1.6, 50.9, 300, 10, 90

In the case of simulation for real meteorological conditions a table which contains the direct and diffuse component of the clear sky. Another input parameter is "linke turbiditatea" which describes the atmosphere's state. Monthly values can be found at http://sunbird.jrc.it/solres/solrespvgis.htm.

The results of the simulation are shown in Fig. 5.

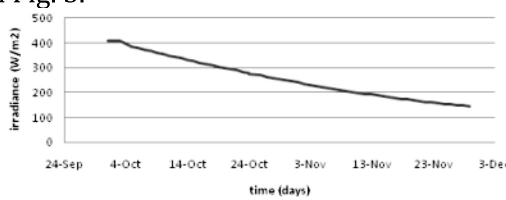

Fig. 5. Irradiance/time characteristic

In Fig. 5, there are represented the average values of irradiance for each day between 01.10.2010 and 31.11.2101.

Experimental results

Experimental data has been collected from the Sunny Boy controller in order to compare predicted results with experimental ones. The sample period was the same as for the simulated results (between 01.10.2010 and 31.11.2101). The results were collected once every 1 hour in the interval 08:00–18:00 (the same as for the simulated results). In Fig. 6 is presented the daily average value for Pac (instant generated power) in watts.

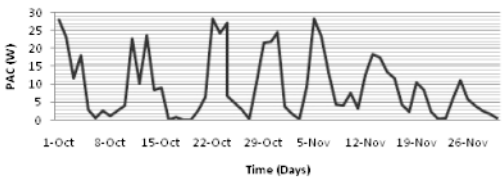

Fig. 6. Daily average value for Pac

From Fig. 5. and Fig. 6. it can be observed the dependence between the solar radiation and the instant power generated. Both graphics have a descendent allure (radiation intensity drops fast from mid October to end of November). In the daily average value for Pac graphic, the descendent allure is not as obvious as for the irradiance/time graphic. The difference can be explained by interference caused by unexpected meteorological phenomena as cloudy sky. Also, from a more detailed comparison (data gathered once every 15 minutes) it can be observed that for the experimental data the peak values register between 08:00 and 10:00 (Pac close to 200 W) and from that point decreases rapidly, the Pac value dropping to 1 W by 17:30. The explanations are:

- The PV window is faced east so the most direct sunlight is during morning time.
- The system is shaded in the afternoon due to the building's architecture.

Conclusions

The paper analyzed the modeling and simulation of a BIPV system implemented at Polytechnic University of Bucharest. The differences between the data received from model simulation and the experimental data gathered from the implemented system show us that the influence of meteorological factors and the system orientation have a great impact on the PV system efficiency.

An important aspect of the simulation results is the loss assessment which can be used to evaluate more accurately the efficiency of the implemented BIPV system. Also, based on the comparison between the simulated and experimental results, a forecast can be made concerning the power generated by the system.

The developed demonstrative BIPV system helps us evaluate and solve the applicability problems which appear at the implementation of such systems. The position of the system (tilt, azimuth) must be carefully chosen as well the architecture of the building on which the system is implemented (from experimental results we can observe that the most negative impact on the system efficiency is because of the long period of time in which the system is shaded).

Acknowledgements – The BIPV system at Polytechnic University of Bucharest was developed within a research partnership project funded by the Romanian Ministry of Scientific Research in the period 2007–2010.

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Hybrid Solar Thermal Systems for Romanian Applications

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The main types of solar collectors commercialized in Romania are analyzed based on their technical performances and prices. There are discussed: Idella Flat plate solar collectors; Idella Vaccum tubes.

The paper presents the concept of hybrid water heating systems based on solar collectors and heat exchanger fed from centralized heat supply grid. For sizing of the proposed system is used a specific software tool. There are presented the results of our market study for analyzed solar collectors together with the results of the simulated hybrid-system based on such solar collectors.

Keywords: solar collector, heat pump, solar thermal, simulation

Introduction

What is Solar Thermal?

Solar thermal water systems use energy gathered from sunlight to heat water. Sunlight falls on collector panels which is then moved to a hot water tank similar to conventional tanks. Many types of solar thermal systems exist some of which are more adapted to small scale and therefore residential use. The systems examined below can be adapted to fit either small scale or large scale water needs. Other systems such as parabolic solar collectors tend to be used for large scale collection and are not examined in this project.

Almost all residential Solar Thermal systems fall in to one of the following two types of systems:

Open Loop systems take water from local water pipes, pass it through the solar thermal panels to then be used directly for hot water. A schematic of such a system can be found to the right.

Closed Loop systems circulate a coolant/ water through the solar thermal panels and transfer the heat using a heat exchanger to your hot water tank. In this system, the water from the tap stays in your water heater while it is being heated and does not travel through the solar thermal panels. A schematic of this

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system can be found to the right.

The lack of pressure inside to tubes allows the boiling of water at a much lower temperature. Heat from the boiling water in the tubes is transferred to another liquid. This heated liquid travels through a house to a heat exchanger near/in the water tank. The heat exchanger again moves the heat out of the liquid and in to the water in the tank.

Flat Plate Collectors are sealed rectangular boxes with heat absorbing metal sheets next to small tubes of water or coolant. This liquid is moved through the house to the heat exchanger near/in the water tank. A schematic of this system can be found here.

What is a Heat Pump?

A heat pump is any device which moves heat from one location to another. Heat pumps operate much like a refrigerator, only in reverse. A refrigerator pumps a refrigerant through a compressor and transfers heat from inside the cooled space to the outside ambient air thus cooling the inside of the fridge. A heat pump on the other hand takes heat from the outside and uses it to heat the inside air or takes inside or outside air to heat water.

There are two types of heat pumps: ground source heat pumps, and air source heat pumps. Either of these types can be used to heat a home or to heat water or both. We chose to do our analysis on ground source heat pumps.

Ground source heat pumps basically work by circulating refrigerant through underground pipes and back through a compressor where it is vaporized, and condensed causing it heat up and then the heat is transferred to a coil where it can be utilized for home heating or water heating purposes. The reason the pipes are run underground is to utilize the consistent 14.44 °C ground temperature which in cold climates may be higher than the average air temperature.

Ground source heat pumps can also be used as air conditioners in the summer months and are more cost effective when used to heat and cool a home.

The proposed hybrid solar system

This project examines a hybrid solar thermal system and heat pump (GSHP) that is commonly used for residential buildings. A spreadsheet comparing factors such as system cost, efficiency, operating costs, maintenance and pollution has been created. We have established that the optimum hot water heating system varies depending on water use needs. For lower water consumption, heat pumps are more cost effective. For higher water consumption, hybrid systems represent an economical choice. Both systems are effective at reducing the consumer's carbon footprint. An actual load for a building in the city of Bucharest was estimated. PolySun, a system simulation software tool, was selected to model the yearly performance of proposed hybrid solar thermal and ground source heat pumps. This study demonstrates that hybrid ground source heat pump system combined with solar thermal collectors is a feasible choice for heating dominated buildings, as well as for space conditioning .

Geothermal applications for buildings are mostly limited to full dependence on ground soil temperature for 100% of the heating and cooling energy. Although there are the advantages of low energy and maintenance costs in favor of this approach, space limitations and high initial costs may restrict a full geothermal installation. Restrictive regulations such as mandating a minimum borehole size, grouting materials, wage rates and heat exchange method, generally increase the cost of such a system. The initial cost may put the project above the budget, and in some cases, the drilling conditions may prevent the use of a large conventional closed-loop borehole field.

In many buildings, annually, the amounts of heat extracted from and injected into the ground are not balanced. The vertical closed loop is a common type of earth coupling mostly used in buildings that have limited land areas. In designing this type of system, consideration must be made of the thermal response of the ground throughout the expected project life (25 years). An annual imbalance in ground load will lead to lower heat pump entering fluid temperatures (EFT) in heating-dominated buildings or higher heat pump EFTs in cooling-dominated buildings, to a point where equipment capacity may be compromised if the ground loop heat exchanger is not long enough. This imbalance requires either a very large ground loop heat exchanger or some mechanism for assisting the system by supplementing deficit heat or rejecting excess heat. Because the cost of installing a very large ground loop heat exchanger may be excessive, there are a number of alternate ways to assist a ground source heat pumps(GSHP). These include solar collector, which injects additional heat into the ground for heating dominated buildings, and cooling tower, which rejects excess heat into the atmosphere for cooling dominated buildings. Systems that incorporate both a ground heat exchanger and an aboveground heat exchanger are commonly referred to as hybrid GSHP. [1,2]

The purpose of this study was to evaluate the performance and viability of hybrid geothermal heat pump systems with solar thermal collectors. The main objective was to perform a system simulation approach to assess the feasibility of this kind of hybrid system in heating dominated buildings in Romania. It would be ideal if this study attracts the interest of researchers and contractors and provides valuable information for designing and installing this kind of hybrid system in heating dominated buildings in Romania.

Two solar collectors in Romania

In Romania there are several solar collectors but the most common used once are as follows :

- Idella Flat plate solar collectors [3];
- Idella Vacuum tubes [3].

Idella flat plate solar collectors

Solar panel dimensions: (Lxlxh): 2242 x 1273 x 97 mm; Gross Area: 2851 m^2; Absorber area: 2.62 m^2; Fluid Content: 1.9 liter; Stagnation temperature: 232 °C; Weight: 49 kg; Absorbent: TINOX; Box: glass-reinforced plastic (GRP); Glass: 4 mm solar glass prism of high security, anti-glare; Insulation: Mineral wool resistant solar.

Connections: 3/4; The distance between headers: 6 mm

Standard: DIN EN 12975-2/ISO 9806-1

Price: 580 EUR

Idella vacuum tubes

Dimensions (Lxlxh): 1358 x 1603 x 140 mm; Number of tubes: 12 pcs

Gross area: 2.16 m; Aperture Area: 1.89 m^2; Stagnation temperature: 262 °C; Operating pressure: 6 bar; Weight: 43 kg

Absorber tube: U copper rod double;

Frame: Aluminum Standard

Price: 875 EURO

Time Performance of solar water heating in the number of hours in a sunny day, depending on volume at 45 °C: 2 h-100 l; 3.30 h-150 l , 5 h-200 l; 7.30 h-300 l.

The solar panels can be used for quickly obtaining of boiling water for industrial processes. Due to its outstanding characteristics, optical and technical vacuum tube solar panels IFVS separates away from the great mass of standard tubes. Suction tube thickness is 58 mm, can be replaced separately and easily provide a high efficient solar thermal energy.

In areas that require higher temperatures reached by the collector tube an ingenious design is considered for a higher heat transfer. Special CPI mirrors optimally located behind the pipes, are arranged at different angles, focus and direct solar radiation for the best absorption by the tube. Evacuated tube is similar to a thermos bottle of high quality integrated double wall. Thus, the vacuum is protected and long-term care.

As pointed out vacuum tube solar panel is more expensive than flat panel. Making a quality-price vacuum tube panel is definitely a better choice in terms of performance. Vacuum tube panels have the advantage that it captures all day radiation emitted from the Sun due to the cylindrical shape of the tube.

Vacuum tubes are better for daily intense use , and flat solar panels are great, thanks to lower prices, for locations with normal use.

System description:

In the figure 1 is shown a schematic of the hybrid thermo solar and ground source heat pump system. The system is constructed from the following major components:

- Ground source heat pump 22 m pipe
- 26 solar vacuum collectors, total area 47.58 m^2
- Storage tank 3120 liter
- Convector 1000W
- Heats pump 23 kW

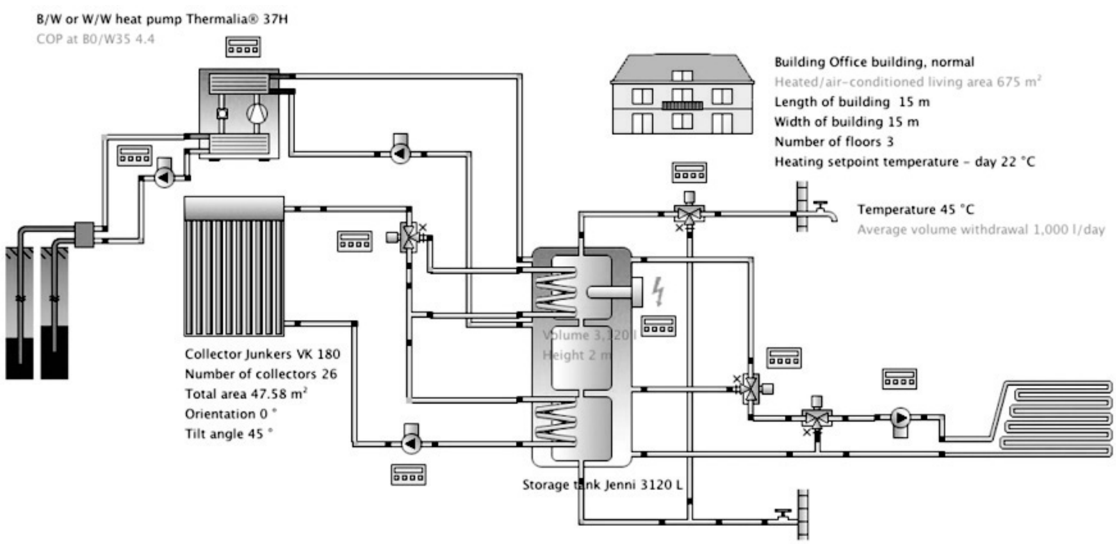

Fig. 1. Hybrid thermo solar and ground source heat pump system (GSHP)

Polysun software simulation

Description of the tool

The Polysun product family includes several different versions and interfaces to one single simulation kernel. The different applications serve several purposes and have different target users, which is described in the following.

Polysun is a well established simulation tool present in the market already for many years. [4]

The main advantage of making one simulation kernel available for several different applications is that reliability and stability of the numerical model and the database increases. Validation of the simulation model is done for all applications at once. Recognition by funding agencies is obtained easily if the same software kernel and the same input data are used as in the standard Polysun. Another key advantage can be seen when observing how the different applications are used in combination with each other: a house owner consults Polysun Online on the internet, passes the results further to the Architect who uses BKI energy planer and works together with planners that use the standalone version of Polysun for the heating system and another partner tool for the building shell. Furthermore, if new technologies (e.g. Solar Cooling, PVT or Power-Heat-Cogeneration) or improved numeric (e.g. faster evaluation of the time-stepping scheme) are implemented, they can easily be made available for all applications.

Simulation results

The graphs below are the result of the system simulation and they are generated through PolySun program.

In this table is the energy needed for the system to generate energy necessary building.

Fig. 2. Energy deficit

The table represents the energy generated by the thermo solar system for one year.

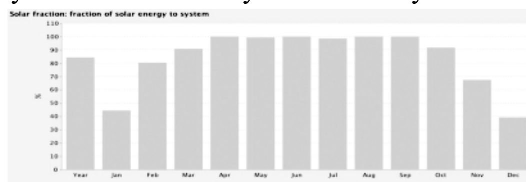

Fig. 3. Solar fraction: fraction of solar energy system

In this table is the energy pumped in the system by the heat pump.

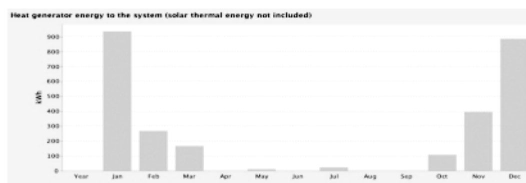

Fig. 4. Heat generated by the heat pump to the GSHP (solar thermal energy was not included)

This table represents the energy transferred by the solar collectors to the fluid.

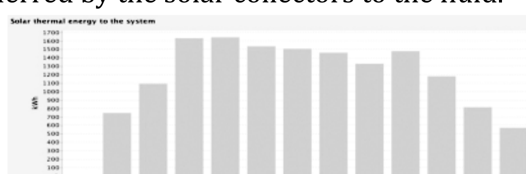

Fig. 5. Solar thermal energy supplied to the system (GSHP)

In this table is represented the energy effectively consumed by the consumers, including the energy consumption for domestic hot water for heating of the building and heat sink.

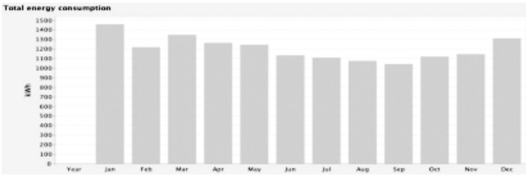

Fig. 6. Total energy consumption

Sum of consumed fuel and electricity from the grid (auxiliary devices and heat pumps included).

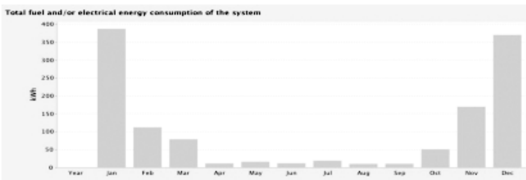

Fig. 7. Total Fuel and/or electrical energy consumed by the heat pump for GSHP

Economical evaluation

The system presented in this paper has an acquisition cost of 25,000 €. For each 1 kWh product we saved 0.2 €. This means that in a year the system will save 800 €. In an economic report the investment made for the heat pump will be payed back in six years, and the investment for solar panels will pay back in 15 years.

Conclusions

In this study, the main performances of hybrid solar thermal and heat pump (GSHP) system were analyzed using powerful simulation tool, Polysun. At the same time the viability of the system was evaluated and existing system problems were detected.

We have shown that the hybrid ground source heat pump system combined with solar thermal collectors (GSHP) could be a feasible choice for heating-dominated houses. The economic benefit of such system depends on the climatic conditions of the selected place.

Acknowledgements - This paper is part of a mastership dissertation regarding Hybrid Solar Thermal Systems, coordinated by Prof. Laurentiu FARA, to be presented in July 2011 session.

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Collegium Geographicum 8. Special Edition, 2011

Technical and Economical Dimensioning of a Grid-connected Photovoltaic System

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This study consists in dimensioning and simulating of a grid-connected photovoltaic(PV)system. The system is a residential building and is situated in Otopeni city, Ilfov county. There are presented the PV system`s technical requirements. Based on simulation software, there are determined the main parameters for PV system dimensioning, as well as energetic performances and a cost evaluation.

Keywords: photovoltaic, solar, dimensioning, simulation, grid-connected

Introduction

Photovoltaic (PV) power systems convert sunlight directly into electricity. A residential PV power system enables a homeowner to generate some or all of their daily electrical energy demand on their own roof, exchanging daytime excess power for future energy needs,[1] (i.e. night time usage). The house remains connected to the electric utility at all times, so any power needed above what the solar system can produce is simply drawn from the utility. PV systems can also include battery backup or uninterruptible power supply (UPS) capability to operate selected circuits in the residence for hours or days during a utility outage.

Basic principles to follow when designing a quality PV system,[2]

- Select a packaged system that meets the owner's needs. Customer criteria for a system may include reduction in monthly electricity bill, environmental benefits, desire for backup power, initial budget constraints, etc.
- Size and orient the PV array to provide the expected electrical power and energy.
- Ensure the roof area or other installation

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site is capable of handling the desired system size.
- Specify sunlight and weather resistant materials for all outdoor equipment.
- Locate the array to minimize shading from foliage, vent pipes, and adjacent structures.
- Design the system in compliance with all applicable building and electrical codes.
- Design the system with a minimum of electrical losses due to wiring, fuses, switches, and inverters.
- Properly house and manage the battery system, should batteries be required.
- Ensure the design meets local utility interconnection requirements.

Basic steps to follow when installing a PV system

- Ensure the roof area or other installation site is capable of handling the desired system size.
- If roof mounted, verify that the roof is capable of handling additional weight of PV system. Augment roof structure as necessary.
- Properly seal any roof penetrations with roofing industry approved sealing methods.
- Install equipment according to manufacturers specifications, using installation requirements and procedures from the manufacturers' specifications.
- Properly ground the system parts to reduce the threat of shock hazards and induced surges.
- Check for proper PV system operation by following the checkout procedures on the PV System Installation Checklist.
- Ensure the design meets local utility interconnection requirements.
- Have final inspections completed by the Authority Having Jurisdiction and the utility (if required).

In this study, a 10 kW grid-connected PV-system is investigated as a case study in Otopeni city for a residential use. Many factors have motivated this study. Firstly, the residential building is located in an area where the global radiation numbers very convenient for a pv system. Secondly, the building has plenty of safe building flat-roof area to install solar panels. Thirdly, most of the power demand is during the daytime so that implementing grid-connected PV system would save considerably in the electric bill.

Finally, constant increase of electric bill cost is due to the increase of oil prices.

In general, PV electrical power generation can be categorized in two categories; standalone PV-system and grid-connected PV-system. The first category is used in remote area where it is too expensive to be reached by public grid system. Big disadvantage of this system is the use of batteries for night supply, since battery energy-loss is too high. The second category is grid-connected PV system where the generated electricity is directly used and there is no need for storage. The connection to the public grid is achieved by using proper inverters. Care must be exercised to choose inverter units with the highest efficiency. During the daytime, the solar generator provides power for the electrical equipment and lighting and excess energy is supplied to the public grid. In addition, during the nighttime, the load gets its electricity from the public-grid. Grid-connected PV-system can be installed in different establishments where the range of power needs can be in magnitude of watts to magnitudes of megawatts. This can be achieved by installing enough PV generators for different establishments [3].

The principal objective of this simulation study is to provide a modular 10 kW PV system that will be connected to the public power grid. Additional PV modules can be added in the future as needed to meet our needs. The software we used for the simulation is called PVsyst, [4] for the both technical and economical simulation.

PVsyst is a PC software package for the study, sizing, simulation and data analysis of complete PV systems. This software is oriented towards engineers, architects, and researchers, and holds very helpful tools for education.

System requirements: characteristics and location

The selected place for the PV system`s sizing and installing is situated in Otopeni city, near Bucharest. It is a residential building with a lot of roof space available for PV modules mounting but we will later see that we will not need more than 100 m^2. The roof is facing east so this is a major benefit. No shading elements will be taken into account because there are none. However, other factors affecting output will be taking in consideration. A PV system produces power in proportion to the intensity of sunlight striking the solar array surface. The intensity of light on a surface varies throughout a day, as well as day to day, so the actual output of a solar power system can vary substantial. There are other factors like standard test conditions, temperature, dirt and dust, mismatch and wiring losses, DC to AC conversion losses that affect the output of a solar power system [4]. These factors need to be understood so that the customer has realistic expectations of overall system output and economic benefits under variable weather conditions over time.

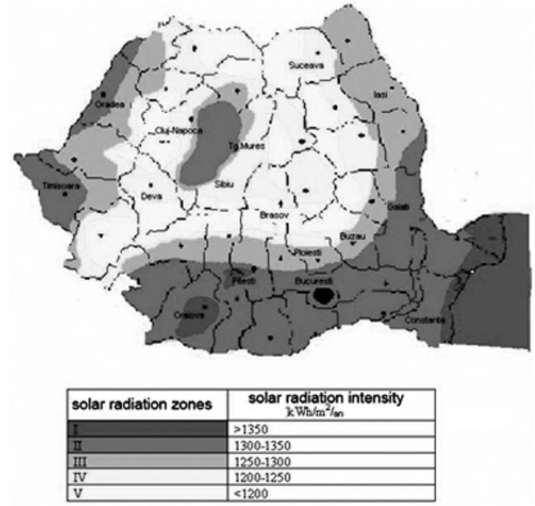

Fig. 1. Global solar radiation map for Romania

PV system dimensioning and simulation

PVsyst is a PC software package for the study, sizing, simulation and data analysis of complete PV systems.This software is oriented towards engineers, architects, and researchers, and holds very helpful tools for education. It includes an extensive contextual Help, which explains in detail the procedures and the models used. It offers an ergonomic approach, with a “greenline” guide, and several project levels. There is also a simulation of the horizontal global irradiation using the data from METEONORM [5] a comprehensive meteorological reference, incorporating a catalogue of meteorological data and calculation procedures for solar applications and system design at any desired location in the world. This proposed 10 kW system will be made of 33 panels. Below you will find the final grid-connected PV system simulation parameters.

Table 1. PV system simulation

Project :	10 kW PV-system			
Geographical Site	Bucharest		Country	Romania
Situation	Latitude	44.5°N	Longitude	26.1 °E
			Altitude	88 m
	Albedo	0.20		
Meteo data :	Bucharest, Synthetic Hourly data			
Simulation parameters				
Collector Plane Orientation	Tilt	30°		
Free Horizon				
No Near shadings				
PV Array Characteristics				
PV module	Si-poly Model	SCHOTT POLY 300		
Number of PV modules	In series	11 modules	In parallel	3 strings
Total number of PV	Nb. modules	33	UnitNom.	300 Wp
Array global power	Nominal (STC)	9.9 kWp	At	8.9 kWp (50°C)
Array operating characteristics		493 V	I mpp	18.1
Total area	Module area	80.1 m^2	Cell area	71.3 m^2
Inverter	Model	SunwaysNT 4000		
Characteristics	Operating Voltage	350-750 V	UnitNom.	3.30 kW AC
Inverter pack	Number of Inverter	3 units	Total	9.90 kW AC
PV Array loss factors				
Thermal Loss factor	Uc (const)	20.0 W/m^{2}K	Uv (wind)	0.0 W/m^{2}K/ m/s
			1 m/s.)	56 °C
Wiring Ohmic Loss	Global array res.	467 mOhm	Loss	1.5 % at STC
Module Quality Loss			Loss	2.0%
Module Mismatch Losses			Loss	2.0% at MPP

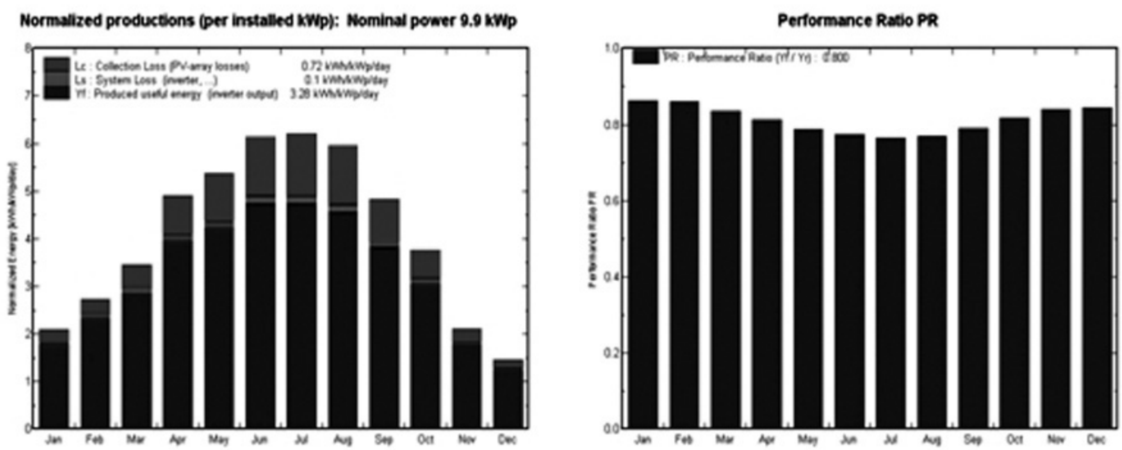

Fig. 2. Normalized production(per installed kWp) and performance ratio

Table 2. Balances and main results

	GlobHor kWh/m²	T Amb	GlobInc kWh/m²	GlobEff kWh/m²	EArray kWh	E_Grid kWh	EffArrR %	EffSysR %
January	41.0	-1.00	64.8	62.7	571	553	11.00	10.65
February	55.0	0.10	76.2	74.0	669	649	10.97	10.63
March	89.0	5.60	106.8	103.5	909	882	10.63	10.31
April	134.0	11.10	147.1	142.5	1219	1184	10.35	10.05
May	168.0	16.70	166.9	161.6	1342	1303	10.04	9.75
June	192.0	20.00	184.4	178.6	1455	1413	9.85	9.57
July	196.0	22.20	192.3	186.3	1502	1458	9.75	9.47
August	175.0	21.70	184.5	178.9	1449	1408	9.80	9.52
September	122.0	17.90	145.2	140.8	1169	1136	10.05	9.77
October	84.0	11.80	116.6	113.1	972	944	10.41	10.11
November	42.0	4.50	63.5	61.4	545	528	10.72	10.38
December	29.0	0.70	45.3	43.8	393	379	10.83	10.44
Year	1327.0	11.01	1493.6	1447.2	12196	11836	10.19	9.89

GlobHor – horizontal global irradiation
TAmb – ambient temperature
GlobInc – global incident in collector plane
GlobEff – effective global corr. for 1AM and shadings
EArray – effective energy at output of the array
EGrid – energy injected to grid
EffArrR – efficiency Eout array / rough area
EffSysR – efficiency Eout system / rough area

Table 3. PV system parameters

Project :	10 kW PV-system Bucharest			
Simulation variant :	PV system parameters			
Main system parameters	System type	Grid-Connected		
PV field orientation	Tilt	30°		
PV modules	Model	**SCHOTT POLY 300**	Pnom	300 Wp
PV array	Nr. of modules	33	Pnom total	9.9 kWp
Inverter	Model	**NT 4000 (850V)**	Pnom	3.3 kW ac
Inverter pack	Nr. of units	3	Pnom total	9.9 kW ac
	Unlimited load (grid)			

Some losses in the PV system are caused by an interaction between the environment, the inverter and modules. In Fig. 3. several types of losses are introduced in the form of a Sankey diagram. The proposed method of analysis consists of a clear definition of these losses on basis of measured simulated quantities. This data will be used in a future attempt to minimize the losses and optimize the system`s performance.

PV system`s economical evaluation

Based on the same simulation software, I have made an economical evaluation of the system. This reflects the prices of the components and calculates the investment taking in consideration several factors like annuities, annual running costs, wirings, etc. This evaluation also reveals the amount of produced energy in one year and the cost of produced energy, two very important aspects of the system`s simulation.

An important economic method of financial analysis that is not mentioned in Table 4. and is often used for making system investment decisions is payback analysis. The payback period is the minimum time it takes to recover investment costs. The payback period for an energy system is calculated as the total investment cost divided by the first year's revenues from energy saved, displaced, or produced. In payback analysis, the unit of measurement is the number of years to "pay back" the investment cost. Momentarily, without the feed-in tariffs that are not implemented in Romania, it is difficult to estimate the payback period. The only way to do this now, is to keep record of the cost of energy provided from the local energy grid and use this data to see what amount of money you save. The payback method is often used as a rough guide to cost-effectiveness. If the payback period is significantly less than the expected system life, the project is likely to be considered cost-effective. In conclusion, implementing the feed-in tariffs in Romania will significantly reduce a photovoltaic system`s final costs and, in the same time, increases the chances that people will find his technology more financial-attractive.

Conclusions

This was a complete configuration of a 10 kW grid-connected PV system located in Otopeni, Romania. Calculations show the cost for PV-generation is 0.34 €/kWh. This cost could decrease further if the feed-in tariff system will be implemented in Romania in the next future. This will reduce the payback time of the photovoltaic system and dramatically increase the likelihood of people investing in this technology.

Most of the PV-system cost comes from the hardware, i.e., the initial cost and portion of it might be covered from public subsidies in the future.

Furthermore, the hardware cost is decreasing with time and oil prices are increasing and this cost ratio, between PV-generation and grid supply, might be reversed in near future. This study is easily manipulative and can be used as a starting point for other future system designs. The power this system generates can easily provide energy for a medium sized family.

We focused on implementing a 10kW PV system in 33 modules. However, more modules can be connected to the grid to meet any additional needs.

Considering the environmental impact, the PV system does not produce CO_2 emission and maintain clean and healthy environment. With this PV system we will be able to avoid emissions of 12 tons of CO_2/year. Future study might include improving system efficiency and optimizing system components. This might be achieved by using a solar tracker to keep the sun radiation vertical to solar-panels, or using newer technologies for solar cells and inverters.

System losses are presented in a Sankey diagram.

Calculated system efficiency and performance ratio will be compared to measured values once the system will be given in use. This approach will result in a more accurate prediction of yearly energy yield with fast characterization of the system and system loss factors and possibly in a efficiency improvement.

Table 4. System economical evaluation

Main system parameters	System type	Grid-Connected		
PV field orientation	tilt	30°		
PV modules	Model	SCHOTT POLY 300	Pnom	300 Wp
PV array	Nr. of modules	33	Pnom total	9.9 kWp
Inverter	Model	NT 4000 (850V)	Pnom	3.3 kW ac
Inverter pack	Nr. of units	3.0	Pnom total	9.9 kW ac
User's needs	Unlimited load (grid)			
Investment				
PV modules (Pnom = 300 Wp)	33 units 1000 €/unit		30000	€
Supports / Integration			3000	€
Inverters (Pnom = 3.3 kW ac)	3 units 2000 € / unit		6000	€
Settings, wiring, ...			1000	€
Substitution underworth			-0	€
Gross investment (without taxes)			40000	€
Financing				
Gross investment (without taxes)			40000	€
Taxes on investment (VAT)	Rate 24.0 %		9600	€
Gross investment (including VAT)			49600	€
Subsidies			-0	€
Net investment (all taxes included)			49600	€
Annuities	(Loan 5.0 % over 20 years)		3980	€/year
Annual running costs: maintenance, insurances ...			0	€/year
Total yearly cost			3980	€/year
Energy cost				
Produced Energy			11.8	MWh / year
Cost of produced energy			0.34 €/ kWh	

Acknowledgements – This work is part of the author`s master degree paper on PV system`s dimensioning, which is currently being elaborated under the coordination of Professor Laurentiu Fara.

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Solar Energy Systems as a Case Study for Welding Applications

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The density of solar energy on the Earth surface is approximately 1000 W/m². The main methods for utilizing solar energy are: agricultural products, biomass, thermal conversion for making hot water, photovoltaic conversion, solar furnaces e.a.
Vegetal biomass consists of organic matter of the plants, made by the photosynthesis process, which occurs in large quantities, although the efficiency of the storage process is less than 0.1%. For a convenient efficiency of the thermal solar panels, the heat carrier (hot water or air e.a.) must not exceed 100–120 °C, so that cheap solar collectors can be made. Semiconductor-based photovoltaic panels have an area of 1.0– 1.5 square metres, 5–15% efficiency and the required investment is 7.50–9.50 $/W. A solar furnace is a mirror or lense-based structure for concentrating solar radiation; such a furnace rated at 1 kW can reach the temperature of 500–1200 °C in the focal area and can be applied for soldering and sticking.
Photovoltaic panels can be applied as ecologic supply systems for both home appliances and industrial equipment, rated with lower power consumption. For instance, welding and allied equipment rated with 0.2–4.0 kVA installed power, on an intermittent regime with a duty ratio 35–50% can be supplied by photovoltaic panels.
Solar energy is an ecologic source of energy, because it is regenerable, non-pollutant and non-emissive. The specific greenhouse emissions of the photovoltaic panels are about 30 times lower than the emissions of a coal-based power plant.

Keywords: solar energy, thermal, photovoltaic, furnace, welding

Introduction

One of the energetical solutions of remarkable interest is solar energy. The Earth receives yearly from the Sun the quantity of energy Q = 2,93 x 1014 kWh. This exceeds the present energy necessities of the society, in all branches: industry, agriculture, transportations, residential and public domains e.a. The density of solar energy radiation on the Earth surface is called solar constant and its value is 1000 W/m². The density of power received under real conditions is 170–1000 W/m² [1, 2].

Maps that show the level of solar radiation in various regions and for the hole surface of the Earth were drawn, as presented in Fig. 1. and Fig. 2. They are

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used for evaluating the technical level of the installations for solar energy.

Solar energy is clean energy, that we can dispose of, in all areas of the Earth, based on a season and day cycle, as well as depending on the wheather conditions. It is important to apply the efficient methods of utilizing the solar energy, depending on the specific requirements in every place.

Fig. 1. Areas of solar radiation in Europe [2]

Technical and economic aspects of using solar energy

Methods of utilizing solar energy are the following: using agricultural products as food, utilizing biomass as fuel, direct thermal conversion or photo-conversion for making hot water, photovoltaic conversion for generating electric energy, solar furnaces with concentrators of solar radiation e.a.

Utilizing biomass

Vegetal biomass consists of organic matter of the plants, which is developed by the photosynthesis process and represents solar energy stored as substance. The efficiency of the storage process is rather reduced, less than 0.1%, but vegetal biomass is present in very large quantities. It is used as agricultural products for food. Vegetal waste can be processed and used as fuel in some residential, agricultural and energetic installations. Such biodiesel fuel can also be applied for autonomous generating units and in the logistics of the welding sites, in remoted areas. [12]

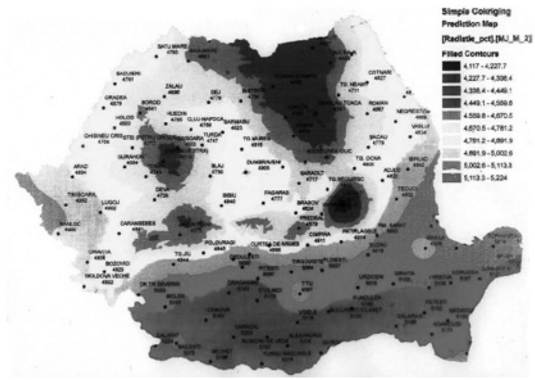

Fig. 2. Areas of solar radiation in Romania [2]

Direct thermal conversion for making hot water

In Fig. 3. a plane solar panel for making hot water is presented, applied for housekeeping, central and technology heating, in the industry and agriculture. [3] Such panels are also applied in the logistics of the welding shops and sites, in towns as well as in remoted areas. [12]

By means of the present technologies of collecting and utilizing solar energy, in order to get a convenient efficiency, it is necessary that the temperature of the produced heat carrier (hot water or air e.a.) should not exceed 100–120 °C, because in this way cheap even-shaped solar collectors, without any sofisticated maintenance, can be manufactured. The rated power of both the home and industrial installations for making hot water is 3–5 kW, which means that the fossil fuel savings obtained by this solution is not negligible.

A type of classic system of solar panels has the following components:

- Two plane-shaped solar collectors, with a total area of 4.22 m^2
- Fixturing system for a tile roof
- Connecting system (fittings for joining)
- Air vent recipient
- Basic controller
- Classic pump group, flowmeter and security device
- Solar expansion vessel, 12 litres capacity
- Thermally isolating and withstanding liquid (glycol), 10 kg capacity
- Bivalent solar boiler, 270 litres capacity
- The guarantee of the solar panel system is 10 years.

Fig.3. Solar panel for hot water [3]

Photovoltaic conversion

For the conversion of solar to electric energy semiconductor-based photovoltaic panels are used, having 5–15% efficiency [4–6]. The most important problem regarding the photovoltaic panels is the investment cost (outfit and installing). The average investment cost is 7,50–9,50 $/W, which consists of photovoltaic panels, fixturing parts, inverters and electric components [6].

Fig. 4. Photovoltaic panels of a solar power plant [6]

Fig. 5. Building-integrated photovoltaic panels system [6]

The applications of the photovoltaic panels are solar power plants [6, 7], rated at 14–50MW, as presented in fig.4, building-integrated systems [6, 8], as shown in Fig. 5., rated with 4–10kW power, supply systems for remote customers and self-suporting equipment.

In Fig. 6. and Fig. 7. some types of photovoltaic panels are presented, for both residential and industrial applications, included for welding [12].

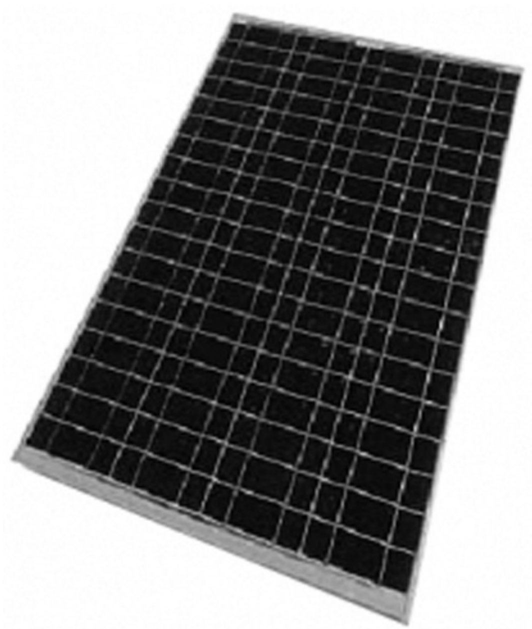

Fig. 6. Poly-crystalline photovoltaic panel with protection screen [4]

Some characteristics of the photovoltaic panels made of polycrystalline semiconductor are the following:

- Conversion efficiency 14%
- EVA screen-based packaging technology is applied for a good protection and high withstanding to the severe operating conditions
- The panel has the aluminium plated frame connected to the anod, for easier mounting and installing, included the connecting plug
- The guaranty is two years for the components, materials and mounting, as well as 25 years for the supplied power, according to the operation conditions secified by the manufacturer, including the allowance level of the product.

Applications:

1. Connection to the mains:
   - Residential solar systems
   - Public and industrial solar systems
2. Independent connection:
   - Remote towns and locations
   - Houses and towns for holidays
   - Radio-relay stations
   - Street utilities
   - Other stand-alone electric systems

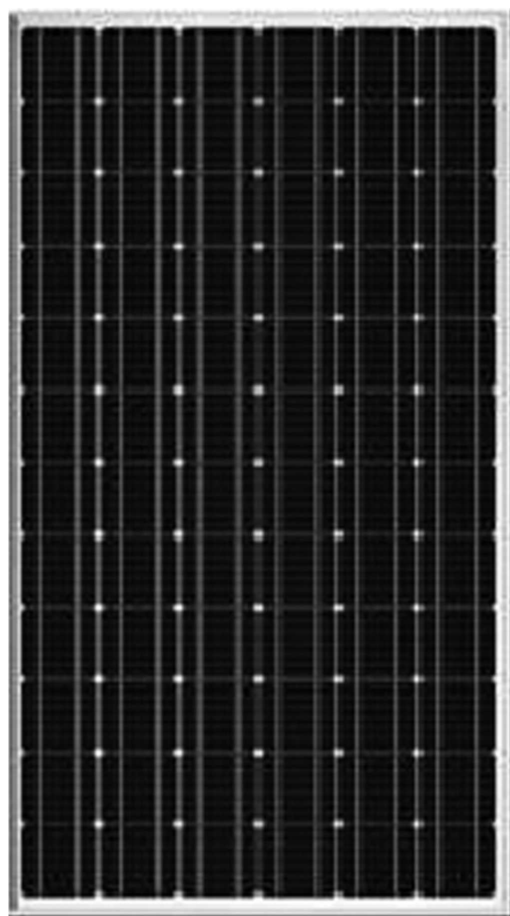

Fig. 7. Monocrystalline photovoltaic panel with anti-reflecting plate glass [5]

The cost of the electric energy production in a photovoltaic panel system is aproximately 0.21 €/kWh, taking into account the utilizing and pay-off period of 25 years. This cost is generally higher than the present average price of 0.08–0.16 €/kWh, for delivering the electric power from the national energetic systems, by means of both classic and nuclear methods. Therefore, in most countries of the European Union and all over the world, subsidies are offered for installing and utilizing photovoltaic panels and other solar systems.

Another photovoltaic panel type consists of 72 solar monocrystal cells of high efficiency, with the sizes 103 mm x 103 mm, covered by an antireflecting plate glass. This module generates 120 W power, having a relatively small surface and a high efficiency related to 1.0 m^2.

Due to the recent Ultratron technology, all modules of this series have both higher efficiency and power. This technology realizes a high level of the characteristics of the panels. They produce energy even under the conditions of less solar light, in some areas, where applications are intended.

In fact, the modules are manufactured of solar cells, laminated between two foils of ethylene vinylacetate (EVA), that are ultra-translucent and shock resistant. They are covered with specially treated 4 mm thick glass, that protects the module against the climat and mechanical effects, such as hail, ice e.a. The rear side, manufactured of a white plastic sheet realizes an additional protection to the module and electric contacts, against climat factors, such as humidity.

The technical characteristics of the monocrystalline photovoltaic panels, measured for the solar energy density of 1000 W/m2, at the ambient temperature of 25 ^{o}C and AM = 1.5, are listed in the Table 1.

Solar furnaces

A solar furnace is a structure utilized for concentrating the radiation of the sun, in order to produce high temperatures, by using a mirror or a lense [9, 10]. The temperature in the focus may reach 3,000 °C. The biggest solar furnace in the world is at Odeillo, in the Eastern Pirrenees Mountains, in France.

Fig. 8. Experimental solar furnace with Fresnel lense [10]

Fig. 9. Experimental solar furnace with parabolic mirror [10]

Table 1. Technical characteristics of the monocrystalline photovoltaic panels

Crt. No.	Technical characteristic	Panel type12 V	Panel type 24 V
1	Maximal power (Wp)	120 W	120 W
2	Rated voltage (Vn)	12 V	24 V
3	Maximal current at maximal power (Imp)	7 A	3.5 A
4	Short circuit current (Isc)	7.2 A	3.6 A
5	Open circuit voltage (Voc)	21.2 V	42.4 V
6	Voltage at maximal power (Vmp)	17.1 V	34.2 V
7	Rated operation temperature of the cell (Tc)	46ºC ±2ºC	
8	Maximal voltage of the system (Vmax)	800 V	
9	Lowest operating temperature (Tmin)	-40ºC	
10	Highest operating temperature (Tmax)	+90ºC	
11	Withstanding to hail	28 mm	
12	Impact speed	90 km/h	
13	Maximal effort on the surface	2400 N/mm^2	
14	Maximal wind speed	200 km/h	
15	Relative humidity	100.00%	
16	Sizes	1310mm x 675mm x 35mm (±2mm)	
17	Weight	11.8 kg	
18	Allowance of the technical data	±10%	

An experimental solar furnace, presented in Fig. 8., having the rated power of approximately 1 kW, is made with Fresnel lenses [10]. In the focal area temperatures as high as 500–1200 °C can be reached in 25–30 seconds. This furnace can be used for welding and cutting parts made of non-ferrous alloys or plastics [12]. Operating this device requires caution, because accidents may occur, because of the high temperature.

Another kind of solar furnace [10] consists of a big sector of a parabolic mirror, a travel unit and a focus, as an operation zone. The incidental solar light upon the 6.87 m^2 collecting surface is focused on a surface less than 0.09 m^2. On a sunny day, the power developed in the focus is about 7.0 kW. This furnace, also called solar forge can be utilized for heating parts made of non-ferrous alloys and other materials, the plastifying temperature of which is 200–500 °C: copper, zinc, gold, plastics. It is applied for forge processing, but also for welding by forging, brazing and soldering [12], as preliminary experiments already revealed. So, they become ecologic processes, that use regenerable solar energy. Ecologic aspects of solar energy installations

Solar energy fulfils all the requirements of the ecologic energy sources, because it is regenerable, non-pollutant and non-emissive.

The solar panels for making hot water, as well as the solar furnaces do not produce any polluting substances during their operation. In the manufacturing process of these installations, up-to-date technologies are applied, without emissions of toxic substances or green-house effect gases.

The emissions of greenhouse effect gases of the photovoltaic panels, during the life cycle are in the range 25–32 g/kWh [6]. For compairing, a gas-based power plant with a combined cycle has emissions of 915 g/kWh. The cadmium quantity used by the photovoltaic thin layer modules is relatively reduced (5–10 g/m^2) [6]. The cadmium emissions are 0.3–0.9 μg/kWh upon the hole life cycle. The cadmium emissions related to the life cycle, produced by coal are 3.1 μg/kWh, those produced by lignite are 6.2 μg/kWh and those produced by natural gas (methane) are 0.2 μg/kWh.

Residential and industrial applications by welding and allied processes

The solar photovoltaic panels can be used as ecologic supply systems for home appliances: refrigerators, lighting devices, radio and TV sets, washing machines, kitchen appliances e.a. [4, 6, 11, 12], as well as for some industrial processes that have a lower energy consumption [12], based on a flexible connecting regime consumergenerator to the electric mains. The consumed energy of such equipment can be compensated fractionally or completely by the energy delivered in the electric mains by a photovoltaic panels system. In remote areas, the necessary energy can be produced in an autonomous system.

For example, the welding sources and the devices for the allied processes represent electric equipment that can operate on power produced by the photovoltaic panels, in a reversible and flexible regime, as both consumer and producer of electric power, respectivelly in an autonomous solar system.

In the case of an autonomous supply system of a source for manual metal arc (MMA) welding, having a rated current of 100 A, for instance, the installed electric power of the necessary system [4, 12] is 2.5–3.0 kVA, which means that 30–40 conventional photovoltaic panels are necessary, each with an area of approximately 1.0 m^2. These can be placed on the roof of a building, intended for this application. The minimal sizes of the roof or roof-top of the building are 4 m x 10 m. The most important problem is the necessary investment of about 40,000 Euro, in this case. The photovoltaic panels system generates direct current, converted to alternating current by the inverter of the system [4, 11, 12].

In the case of utilizing a storage system for the electric energy obtained by the conversion of the solar energy, the amount of the photovoltaic panels can be reduced to 4–6 panels [4, 12], which drastically reduces the investment.

In Fig. 10. the block schematic is presented, of an autonomous supply system of photovoltaic panels. This system can be utilized for a dwelling, as well as for industrial activities in remote areas, included for welding [12].

The welding equipment classes that can be supplied from photovoltaic panels systems, on an intermittent operating regime with a duty ratio DA 10–35% or even DA 35–50%, are the following [12]:

1. Manual metal arc (MMA) sources, rated on 100–150 A welding current, with the installed power of 2.5–3.0 kVA.
2. Stored energy welding sources, having a rated welding current of 200–250A, with the installed power of 2.5–3.0 kVA.
3. Stud welding sources, having a rated welding current of 200–250A, with the installed power of 2.5–3.0 kVA.
4. Ultrasound welding equipment, with the installed power of 0.8–3.0kVA.
5. Friction stir welding (FSW) equipment, with the installed power 3.7–5.0 kVA.
6. Resistance spot welding equipment, with the installed power 3–10 kVA.
7. Laser welding and cutting equipment, with the installed power 3.7–5.0 kVA.
8. Equipment for resistance welding of plastics foils an bags, having the installed power 1.0–2.0 kVA.
9. Equipment for resistance welding of polyethylene tubes, having the installed power 2.0–4.0 kVA.
10. Other types of equipment for resistance welding, brazing, soldering and other joining processes, having the installed power 0.180–2.0 kVA.

The above mentioned equipment types are made by use of up-to-date technologies and they have high efficiency, so that their consumption is the lowest, in each of the considered classes.

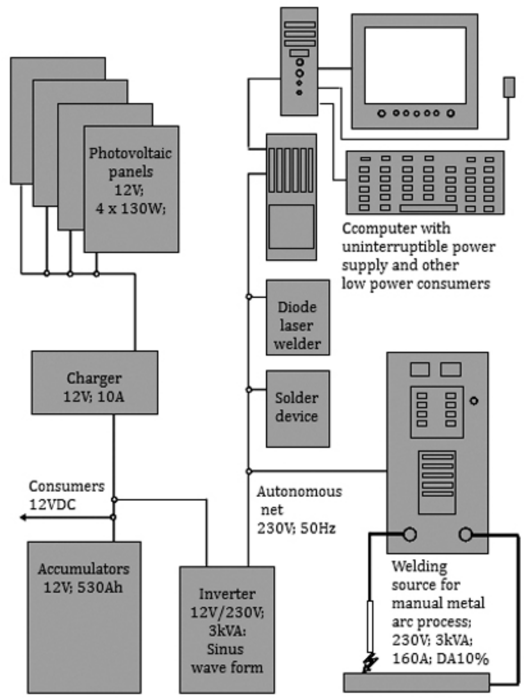

Fig. 10. Autonomous electric system, with photovoltaic panels, for welding

Conclusions

1. The density of solar energy radiation upon the soil surface is in the range 170–1000 W/m^2, which shows that it can be efficiently collected.
2. The efficiency of the photovoltaic conversion is 5–15%, depending on the applied semiconductor material (Si, GaAs, CdTe, etc.), its structure (amorphous, polycrystal, mono-crystal) and the technology.
3. The average energy produced by a photovoltaic panel is 3–7 kWh/m^2 per day.
4. The average investment cost of a complete system of photovoltaic panels for buildings is 7.50–9.50 $/W.
5. The purchasing price of the electric power produced in building-

integrated photovoltaic panels systems (offered to natural persons and companies) is 0.45–0.55 €/kWh, in some countries of the European Union.

6. Due to their cut of emissions, building–integrated or autonomous photovoltaic panels systems, rated on 4–10 kW can be used as ecologic supply of some equipment for welding and allied processes: soldering, brazing and cutting of non-ferrous metals and alloys, as well as plastics.
7. The emissions of greenhouse gases of the photovoltaic panels are 25–32g/kWh, compared to 915g/kWh by a coal-based power plant, related to the life cycle of 25 years.
8. Solar furnaces of 1–7 kW, manufactured with parabolic mirrors or Fresnel lenses can be applied to soldering, brazing, cutting and forge welding of non-ferrous metals and alloys, as well as to welding plastics.

Acknowledgement – This paper is based on a research project performed by the National Research & Development Institute for Welding and Material Testing-ISIM of Timisoara, financially supported by the National Authority for Scientific Research ANCS, of Romania.

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Efficient Thermal Power Plants with Heat Recovery

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Population growth and technological progress imply power and heat consumption increase, while primary energy reserves (carbon-based fuels and nuclear fuels) are reduced.
Considering the current situation, a first solution to solve the energy crisis is increasing the efficiency of existent power plants and reducing power consumption. The increase of a thermal power plant efficiency can be achieved by optimizing the thermal cycle, by reducing the cold source temperature and by increasing the heat recovery from hot cooling water.
Since the optimization of a thermal cycle of an existent power plant involves changes in the equipment, which can be achieved only with large investments, this paper presents a solution for reducing the cold source's temperature with heat recovery from hot cooling water.
The new method of reducing the cold source temperature for open, mixed or closed circuits may lead to the increase of the unitary power of a thermal power plant with 2–4 % and the recovery of a thermal energy amount of two times the unitary power of the thermal plant for a temperature level of 45–120 °C without increasing fuel consumption.

Keywords: electric, thermal power plant, efficiency, heat recovery

Introduction

The population growth and the technological progress require the increase of electric and thermal power consumption while the primary energy resources (coal-based fuels and nuclear fuel) are getting smaller. On the other hand, the production of electric power from carbon-based fuels is a source of pollution leading to the green-house effect and global warming.

Considering the existing circumstances a first solution to solve the energy crisis is to increase the efficiency of the existing thermal power plants and to reduce the energy demand.

To transform the primary energy in electric power employing fossil fuels is

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accompanied by burn-up processes that result in polluting the environment. The demand for energy is increasing year by year, except the periods of crisis, and that is leading either to the depletion of traditional fuel resources and to a very high pollution (including greenhouse effect gases) that negatively affect the environment and population health, specially in urban centers. The modification of the current energy system cannot be accomplished over the night but it requires several years. For that reason to increase the energy output efficiency of the existing power plants and to reduce the energy consumption represent a transition solution which must be considered.

One of the solutions to reduce pollution and to save the primary energy resources is to find technical solutions to increase the unitary power output of the existing thermal power plants without increasing the fuel consumption.

Considering the thermal-dynamic processes in a Rankine – Hirn cycle of transforming the thermal power into mechanical rotation power and finally electric power, it results that the solution to increase the unitary power output of thermal power plants may be accomplished by optimizing the associated thermal cycles and/or by reducing the temperature of the cold source along with the recovery of thermal energy from the recycled warm water. Bearing in mind that optimizing a thermal cycle in a thermal power plant is requiring changes of equipment that , in their turn require large investments, this paper presents solutions to reduce the temperature of the cold source in an open , combined and closed circuit.

Reduction of the cold source temperature in open circuit

In many cases the cooling water in open circuit is taken from the sea and ocean surface water and such an option shows the following disadvantages:

- large variations of temperature function of the weather conditions and season;
- water is polluted and contains microorganisms that may develop and deposit on the heat transfer pipes reducing thus the heat exchange and the power output

The proposed technical solution consists in taking the cooling water from the sea or ocean depth (150–500 m deep) where the temperature is independent on the season and ranges between 5–15 °C. Such water is clean, contains no microorganisms and its salt contents is minimum. The reduction of the cold source temperature by 10–20 °C result in a power output increase of about 2–3%.

For example, with a unitary power of 1000 MW, one may obtain a power increase of 20–30 MW. In this case the additional power obtained in one year by the proposed improvement is almost equal to the energy obtained from 100 wind power plants of 2.5–3 MWe while the required investment is about 100 times smaller.

The additional energy produced as a result of the improvement is the “green energy” because there is no additional fuel consumption for producing and furthermore, the thermal pollution at the water intake is eliminated. Also, the pollution in the water intake area is reduced by bringing a large volume of clean water from the deep sea/ocean to the surface.

The proposed technical solution to bring a large volume of clean water to the surface is presented in Fig. 1. and Fig. 2. It consists in the construction of a network of collectors connected to a sealed, half - flooded housing via a intake pipe network made-up of 2–4 pipes installed in parallel. The pipes and collectors are usually made of high density polyethylene of 1–1.6 m diameter, so anchored on the housing bottom to provide the required adjustable slope.

A level difference of 4–8 m between the free surface of the water volume and the housing is maintained by vertical pumps that provide a 7–10 m/s velocity of the water collected from the depth and a 20–60 m^3/s flow rate, sufficient enough to provide the required cooling water for a 500–1000 MWe thermal power plant.

For providing the above flow rate, the required power for the cooling water pumps is doubled if compared to the power required to take the surface water and it is varying between 4–8 MWe.

Considering the thermal power plant increase of power due to the reduction of the cold source temperature employing this technical solution, it is possible to obtain a real power gain of 10–22 MWe.

Also, the costs and problems related to maintenance of the cold source are reduced, meaning that the number of condenser pipe cleanings are reduced because with this solution the water is clean.

The installation to obtain a thermal energy source of a low temperature in open circuit is made-up of a clean cooling water collection module with the water temperature at 5–15 degrees Celsius and a cooling water supply module. The collection module is made-up of collector sub module, a transport sub module and a reservoir sub module, located sequentially from the depth towards the surface by means of some modules anchored in a fluid environment that may be an ocean, sea or another source, with a free surface and a surface in contact with the ground. The depth of the collectors is imposed by the temperature variation and the water salinity with depth. The installation can provide a cooling water flow at a low and constant temperature for the cold source.

The required investment for the rehabilitation of a thermal power plant falls-in 2% and 5% of the investment required to construct it.

If this solution is applied to a 1000 MWe thermal power plant cooled by surface sea water, one can obtain a power output increase of 25–30 MWE simultaneously with the reduction of the water temperature by 5–10 °C within the discharge area.

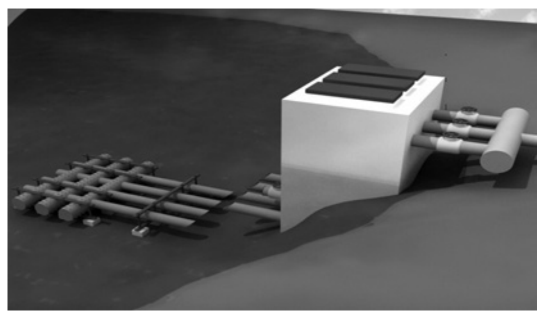

Fig. 1. Open cooling circuit. System for cooling water intake from the depth. Side view

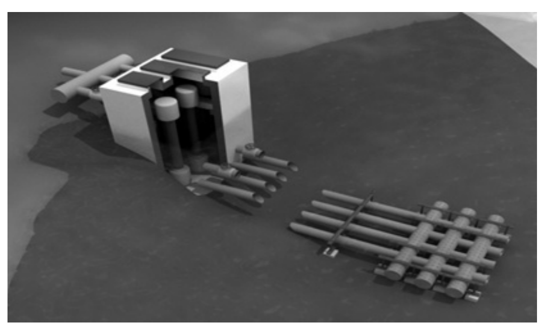

Fig. 2. Open cooling circuit. System for cooling water intake from the depth. Bird-eye-view and section of the pump house

Cold source temperature reduction in a combined or closed circuit

The cooling towers with natural or forced air circulation largely used now-a-days for providing a cold source in a closed or combined circuit have the following disadvantages:

1. the obtained cooling water temperature is quite high and dependent on the weather and season conditions;
2. thermal energy is not recovered from the warm cooling water;
3. a large surface and construction site is required;
4. high cost initial investment.

This paper presents a new procedure to obtain a cold source in a closed or combined circuit which may eliminate to a great extent, the disadvantages of the cold source used today in combined or closed circuits (Fig. 3.).

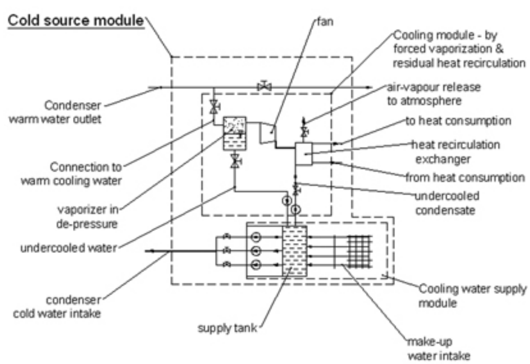

Fig. 3. Flow Sheet for reducing the cold source temperature in a combined or closed circuit

The solution consists in a forced vaporization in depression, in a sealed housing of a fraction encompassed between 1–3% of the cooling water flow. Inside the housing there is a mixture of air a vapor with a de-pressure depending on the relation between the air mass and the vapor mass and the desired temperature of the cooling water. The de-pressure and the vapor concentration in the air mass is so selected that the partial pressure of the vapor in the mixture should be below 0.02 bar for to provide a 15 °C temperature of the cooling water.

The depressure is obtained by means of fans and the air-vapor mixture is either released to the atmosphere, or conveyed to the heat exchangers for recovering the thermal energy at a temperature dependent on the air-vapor mixture pressure (Fig. 4.).

The de-pressure inside the vapor housing and the concentration of vapor in the air inside the housing are set by an optimizing analysis considering the power gain at the turbine, by reducing the temperature in the condenser, the power demand for compressing the air-vapor mixture and the quantity of thermal energy recovered from the warm cooling water.

The installation may operate at a low de-pressure of the air-vapor mixture when the parameters are close to the forced cooling towers with large cooling water temperature control facilities up to a high de-pressure when the housing contains only vapors, case in which it is possible to recover the thermal energy in steps till the desired temperature.

For the cold source of a thermal plant it is recommendable to use several types of modules in parallel. Some of the modules are operating with an air-vapor mixture with low de-pressure but in that case residual heat is not recovered. Some others are operating with a air-vapor mixture with high de-pressure and recovery of the residual heat from the cooling water. A small number of modules may operate only in vapor atmosphere. For that it is recommendable to recover the residual heat in several steps.

The energy recovered by in-step compression of the resulted steam may be also used for pre-heating the condensate in the Rankine-Hirn cycle of the thermal plant following that all the steam be de-compressed via the turbine, Such a thing shall lead to the increase of the produced mechanical work.

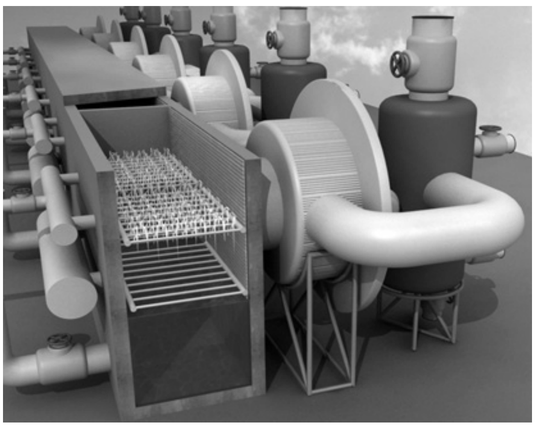

Fig. 4. Closed or combined cooling circuit. Cooling system with forced release in de-pressure, in air vapor mixture

Conclusions

The procedure to reduce the cold source temperature for an open, combined and closed circuit shows the advantages listed below, by comparison with the today solutions :

- it provides the reduction of the cold source temperature by 5–15 °C by comparison with the current solutions;
- it allows the recovery of the thermal energy from the warm cooling water and its use for heating, industrial processes and pre-heating the condenser in the Rankine-Hirn cycle of thermal plants;
- it leads to the increase of the unitary output power of a thermal plant by 2–4% without increasing the fuel consumption;
- it reduces the maintenance costs related to cleaning the condenser cooling pipes because the cooling water is clean and contains no micro-organisms;
- the investment costs associated to the construction of the installation as per the new procedure are relatively small;
- with the open circuit, pollution in the intake area is reduced by the dilution of the surface water with clean water from the deep and the elimination of thermal pollution.

SITON in cooperation with other partners , has been involved in a research program dedicated to the application of the new technology capable to solve some actual cases so to highlight the advantages of the new procedures in reducing the cold source temperature in a thermal plant.

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Sunshine Duration in Western Romanian Plain

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Sunshine duration was analyzed for the Western Romanian Plain. Data recorded in 10 weather stations for a 49 years period (1961–2009) were considered. In order to identify trends in the data sets, Mann-Kendall test and Sen's slopes estimates were used while for probability values HYFRAN software was employed. Main results of the research are: annual duration varies, generally, between 2150 and 2300 hours/year, with the lowest values specific to the stations located near the Danube River; positive slopes were found for the entire area for the great majority of the data sets, except autumn; For the higher probability the longer sunshine duration was calculated for the northwest of the area. For the lowest probability, the longer sunshine is specific to the central-western area and the shortest sunshine duration characterizes the stations located near the Danube river and.

Keywords: sunshine duration, trend, probability, Mann-Kendall, HYFRAN, Romanian Plain, Romania

Introduction

The solar radiation and the sunshine duration are very important in the context of recent climate change, since their variation might show some indications of anthropogenic disturbances [2, 15]. Sunshine duration is very important factor for implementation of solar energy infrastructure. Many studies considered this parameter in terms of total duration, trends or extreme values [2, 3, 14, 19, 21, 22], while some other papers analyzed the connection between sunshine duration and other meteorological parameters [5, 16, 20] or the association of sunshine duration and specific human diseases [12].

Data and methods

Data

Data recorded in 10 weather stations from Western Romanian Plain were used in elaborating the present study. Two weather stations located on the hilly areas

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in the North of the plain were included. The chosen stations are representative for the plain area and they cover quite well the analyzed area. The absolute altitude of the stations above the Black Sea level ranges from 36 m (Bechet) to 317 m (Pitești). The geographical position was shown in Fig. 1.

Fig. 1. Position of the weather stations considered

In Romania, like in other regions in Europe, some stations have not very long data series. The great majority of the stations began their recording after 1960. For some stations where recordings began earlier, the most of the inhomogeneities in the series were found during the first half of the XXth century [17]. Owing to historical and political conditions, some data were lacking, particularly during the two world wars.

Finally, we decided to use for this paper 49 years long series (1961–2009) with homogenized continuous data series provided by National Meteorological Administration. For each station, 17 data sets were considered: 12 monthly data series, four seasonal data series and the annual data series.

Methods

Mann-Kendall test and Sen's slope

The Mann-Kendall test and the Sen's slope estimation were used in order to detect if there are changes in the sunshine duration (considering all data sets).

Calculation of the trend and slope were made by using the Excel template MAKESENS (Mann-Kendall test for trend and Sen's slope estimates), developed by researchers of the Finnish Meteorological Institute [18]. In Romania, the same method and software have also been used with good results to identify trends in different data series (temperature, precipitations, fog, snow cover) [4, 7, 13]. Also based on the use of the Mann-Kendall test, some authors identified increasing or decreasing trend in the sunshine duration [2, 3, 14, 19, 21].

The procedure is based on the nonparametric Mann-Kendall test for the trend and Sen's nonparametric method for the magnitude of the trend [10, 11]. Sen's method uses a linear model to estimate the slope of the trend, and the variance of the residuals should be constant in time.

The MAKESENS software performs two types of statistical analyses: first, the presence of a monotonic increasing or decreasing trend is tested with the nonparametric Mann-Kendall test and then, the slope of a linear trend estimated with Sen's nonparametric method is computed [6]. In MAKESENS, the tested significance levels (α) are 0.001, 0.01, 0.05, and 0.1. Both methods are used here in their basic forms.

Probability

The probability for different return period was calculated using the DEMO version of HYFRAN software, developed by Chair in Statistical Hydrology, INRS-ETE. HYFRAN (HYdrological FRequency

ANalysis) is a software used to fit statistical distributions. It includes a number of powerful, flexible mathematical tools that can be used for the statistical analysis of extreme events. It can be also perform more basic analysis of data time series [23].

For this paper, return periods of 1.001, 2, 5, 10, 20, 50, 100, 200, 1000 years, respectively the occurrence probability of 99.9%, 50%, 20%, 10%, 5%, 2%, 1%, 0.1% were chosen.

Results and discussions

General features of the sunshine duration

Romanian Plain is one of the regions with the highest sunshine duration in Romania. In its western part, annual duration varies, generally, between 2150 and 2300 hours/year. The lowest values, usually under 2200 hours/year are specific to the southern stations, located near the Danube river (Turnu Magurele, Bechet Calafat), while the highest values, above 2250 hours/year were recorded in central part of the area, considering latitude (Bailesti, Rosiorii de Vede, Alexandria) (Table 1., Fig. 2.).

The maximum annual duration analysis revealed values that range from 2450 to 2750 hours/year. The spatial distribution seems to be like the average values, with lowest values recorded in the southern of the region.

Minimum annual values vary from almost 1300 hours/year to almost 2000 hours/year.

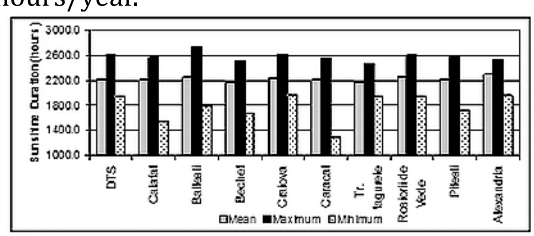

Fig. 2. Annual sunshine duration

Table 1. Annual sunshine duration (hr)

Station	Mean	Maximum	Minimum
DTS	2221.2	2624.9	1934.6
Calafat	2201.6	2568.6	1537.0
Bailesti	2250.2	2729.7	1794.2
Bechet	2167.3	2507.7	1665.2
Craiova	2230.6	2626.8	1956.4
Caracal	2205.1	2554.8	1290.2
Tr. magurele	2162.5	2461.1	1941.9
Rosiorii de Vede	2254.0	2609.3	1945.5
Pitesti	2219.9	2597.8	1712.7
Alexandria	2291.0	2527.5	1955.6

When seasonal sunshine duration is analyzed, one can notice that for winter, mean values are from 230 to 300 hr/season, while minimum values are, usually less than half compared to those values (Table 2., Fig. 3.).

When maximum values are considered, the recordings indicate values between 370 and 480 hr/season.

Table 2. Winter sunshine duration (hr)

Station	Mean	Maximum	Minimum
DTS	257.4	451.0	113.1
Calafat	249.3	429.7	115.7
Bailesti	251.2	478.9	95.2
Bechet	228.0	406.6	104.1
Craiova	247.0	408.9	115.2
Caracal	232.2	384.6	88.6
Tr. magurele	235.0	377.3	129.5
Rosiorii de Vede	249.3	389.6	132.6
Pitesti	301.6	450.9	138.4
Alexandria	250.2	411.5	129.6

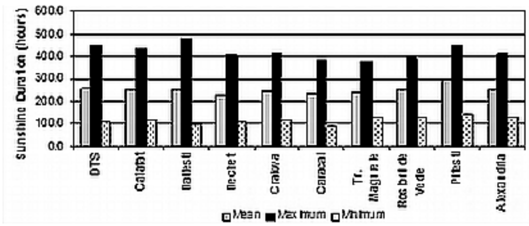

Fig. 3. Winter sunshine duration

Thus, the connection of the two circulation types is made in the central and partially eastern area considered for this paper. It generates higher cloudiness and short sunshine duration.

In the summertime, sunshine duration is the highest. It is about 40% of the annual duration, both for mean and maximum values for the great majority of the analyzed locations. Mean values range from almost 850 hr/season to more than 910 hours/season (Table 3., Fig. 4).

The minimum values usually do not go less than 700 hours/season, while the maximum are generally 1000 hours/season. The highest values, both for mean and for maximum, are specific to stations located westward.

Table 3. Summer sunshine duration (hours)

Station	Mean	Maximum	Minimum
DTS	891.3	1079.8	750.8
Calafat	900.6	1050.5	779.9
Bailesti	905.0	1114.6	721.1
Bechet	894.1	1031.6	762.1
Craiova	887.6	1072.6	768.3
Caracal	895.9	1077.3	656.4
Tr. magurele	871.6	1022.2	786.0
Rosiorii de Vede	896.0	1038.4	721.1
Pitesti	848.7	1019.9	705.8
Alexandria	910.8	1036.4	772.0

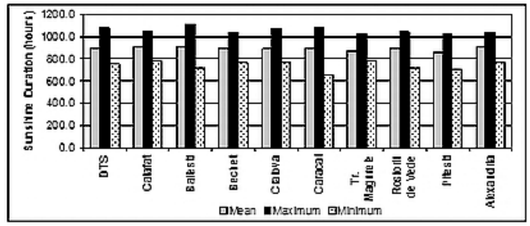

Fig. 4. Summer sunshine duration

Trends in sunshine duration

Calculation of trends for data sets of each station revealed increasing trends for the entire area for the great majority of the data sets (Table 4.). Thus, statistically significant positive slopes were found for all annual, winter, spring and February data series.

Increasing trends were calculated also for summer series (excepting Craiova station), but they are not always statistically significant. Bailesti station experienced only statistically significant positive trends for all the data series considered (less than September series, which has a increasing trends also, but not statistically significant). The annual slopes ranged from 25 hours/decade to 136 hours/decade, representing from 0.7% to 6.2%.

Decreasing trends are specific for autumn, with four statistically significant series. September and October series were also found to have decreasing trends fort the area under study. For some stations, August and November have negative slopes, too.

3.3. Probability of occurrence

Probability of occurrence for different return period was also calculated for annual values. Thus, if for a probability of 99.9% values of 1600 and 1900 hours/year are specific, for a probability of 50%, sunshine duration higher than 2200 hours/year were calculated (Table 5.).

Table 4. Sunshine duration trends (hours/decade) (is 0.001(***), 0.01(**), 0.05(*), and 0.1(+))

Data set	1	2	3	4	5	6	7	8	9	10
J	5.970	7.323*	14.400***	4.038	5.558+	6.733+	6.027	7.188*	4.000	5.885
F	10.286**	9.774*	17.556***	10.634**	12.561**	11.200**	10.963**	12.333**	9.458*	13.950**
M	8.608*	3.250	14.528**	7.677*	10.282*	6.105	9.846*	7.000+	7.017+	6.913+
A	4.538	2.739	14.000***	8.156*	3.905	5.840	3.667	2.324	3.611	2.718
M	5.523	2.778	15.429***	11.878**	1.026	9.857*	6.056	4.436	7.286+	9.031*
J	7.013+	4.000	19.222***	7.971*	1.669	10.920*	6.962+	0.313	1.500	10.293**
J	3.700	1.667	12.840**	5.178	-2.468	4.474	2.545	0.773	4.663	10.250*
A	0.803	-2.135	7.190*	3.481	-3.642	-0.826	0.714	-0.382	2.762	0.417
S	-4.957	-5.000	3.500	-7.463+	-9.498*	-9.091*	-4.000	-2.850	-9.093+	-12.199**
O	-3.652	-4.833	6.000+	-1.751	-6.267	-4.909	-4.655	-4.438	-4.958	-5.948
N	1.196	-0.947	6.478+	-0.496	0.345	-0.619	1.093	-0.308	-0.716	2.262
D	1.644	1.786	8.643**	0.283	1.699	1.967	4.400*	4.500+	1.852	1.877
Annual	47.588**	25.500+	139.235***	53.829***	16.495	45.960**	42.273**	34.400*	27.535+	40.461**
DJF	20.177**	22.308*	44.182***	19.247**	23.959**	25.188**	24.955***	24.641***	19.141**	23.564**
MAM	22.723***	11.600+	43.727***	31.873***	16.188**	22.813**	21.333**	17.000+	19.029**	21.589**
JJA	11.071	2.800	38.750***	15.867*	-5.804	17.391*	11.654	1.429	12.866	18.133*
SON	-6.236	-11.640	16.083*	-13.181+	-15.129*	-11.553	-7.810	-8.750	-16.297*	-18.313**

Table 5. Sunshine duration occurrence probability

Return period (years)	Occurrence probability (%)	1	2	3	4	5	6	7	8	9	10
1.001	99.9	1810	1710	1600	1670	1840	1610	1850	1840	1780	1920
2	50	2220	2200	2240	2150	2230	2200	2210	2250	2220	2290
5	20	2340	2350	2440	2300	2340	2380	2310	2370	2350	2400
10	10	2400	2430	2550	2380	2400	2480	2370	2440	2420	2450
20	5	2460	2490	2650	2440	2450	2560	2410	2490	2470	2500
50	2	2520	2570	2750	2520	2510	2660	2460	2550	2540	2560
100	1	2560	2620	2830	2570	2550	2720	2500	2590	2590	2600
200	0.5	2600	2670	2890	2620	2590	2790	2530	2630	2630	2630
1000	0.1	2680	2770	3040	2720	2670	2910	2600	2710	2720	2700

Legend: 1 – Drobeta Turnu Severin; 2 – Calafat; 3 – Bailesti; 4 - Bechet; 5 – Craiova; 6 – Caracal; 7 – Turnu Magurele; 8 – Rosiorii de Vede; 9 – Pitesti; 10 – Alexandria.

For the return period of 100 years, values above 2500 hours/year are specific, while for a return period of 1000 years the annual sunshine duration may be between 2600 and 3100 hours/year. For the higher probability the longer sunshine duration was calculated for the northwest of the area. For the lowest probability, the longer sunshine is specific to the central-western area and the shortest sunshine duration characterizes the stations located near the Danube river and.

For the higher probability the longer sunshine duration was calculated for the northwest of the area. For the lowest probability, the longer sunshine is specific to the central-western area and the shortest sunshine duration characterizes the stations located near the Danube river and.

The results of the study are encouraging in terms of using solar energy as a real alternative to conventional energy types, because increasing trends of sunshine duration during winter and spring. This means that the increasing in solar energy utilization for a longer period exactly during that period of the year when it is, presently, in deficit.

Conclusions

Studying the sunshine duration in Western Romanian Plain, few important conclusions were reached at.

Thus, annual duration varies, generally, between 2150 and 2300 hours/year, with the lowest values specific to the stations located near the Danube River.

In the summertime, sunshine duration is the highest, counting about 40% of the annual duration, both for mean and maximum values.

Considering trends, positive slopes were found for the entire area for the great majority of the data sets. Thus, statistically significant positive slopes were calculated for all annual, winter, spring and February data series. For summer series, increasing trends were also determined with one exception only.

Decreasing trends are specific for autumn and, especially, for September and October series.

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Modeling Radiation Conditions of Hernád-valley in GIS Environment

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The spatial distribution of incoming solar radiation is highly determined by the surface characteristics. The interpolation methods of radiation data coming from observation stations do not produce adequate information regarding spatial distribution. GIS techniques can handle surface characteristics with high accuracy, but solar radiation is calculated by parameterization of the atmospheric conditions. This fact also induces inaccuracies in global radiation modeling.
In this study a good resolution solar radiation map is generated including Hernád-valley area using ArcGIS software. In the first step the model parameterization scheme is used to obtain the global radiation distribution. Then one pixel of the map is verified by ground base measurements in order to calculate the RMSE between the real and modeled values. In this way the whole global radiation map can be corrected by this error, enhancing its accuracy.
The method presented above can be used to create more accurate radiation maps which would offer crucial information concerning solar radiation applications, and also in forestry and ecological interventions.

Keywords: global radiation, atmospheric transmissivity, GIS

Introduction

The incoming global radiation is determined on the one hand by the astronomical factors (the length of the day, inclination angle), and on the other hand by the terrestrial characteristics, mainly by the orography. The variation of these factors in space and time can be described exactly with mathematical expressions. In the same time the spatial and temporal distribution of global radiation is highly influenced by the components of the atmosphere, which has key role in modifying the way of radiation by reflecting, absorbing and diffusion. Globally only 58% of incoming solar radiation detected at the upper limit of the atmosphere reaches the surface [6]. This effect of the atmosphere on the incoming solar radiation can be quantified only by measurements, otherwise parameterization is needed.

In the case of surfaces with variety relief the main actor in the spatial distribution of

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global radiation is the topographic features followed by the atmospheric conditions [5].

In the literature there are numerous methods of modeling the components of solar radiation [1], but in the same time this methods must be connected to GIS environments in order to analyze the solar radiation of a region [3, 4]. These GIS programs are able to handle the surface characteristics with very high accuracy but their weakness is that the meteorological conditions (cloudiness, water vapor content etc.) are integrated indirectly using parameterizations. This fact can induce large inaccuracy in modeling spatial distribution of global radiation [2].

In this study the ArcGIS software was apply in order to calculate the radiation components of Hernád-valley, Hungray validating the outputs by field measurements. In this way the accuracy of final global radiation map is significantly improved.

Data and methods

Digital elevation model

The digital elevation model used in this study is retrieved from ASTER GDEM dataset elaborated by NASA-METI. The row raster dataset obtained by remote sensing methods is converted into Stereo 1970 projection, and then a 10 m contour file is generated. In the following step a vector TIN model is created from this file, then from this vector file a 30 m resolution raster digital elevation model is elaborated. The small local errors appearing on this DEM are reduced by smoothing filter.

Ground-based global radiation data

The outputs of global radiation data modeled in GIS are validated by field measurements performed by a calibrated pyranometer located in the investigated area (Kosice airport meteorological station, Slovakia). In the study hourly global radiation data are used for the period of May 2009 – April 2010. The original unit of the dataset is J/cm^2 is converted into Wh/m^2.

Modeling global radiation in GIS environment

GIS methods are widely used in modeling spatial distribution of natural phenomena. The ArcGis program of ESRI has a separate module incorporated, namely Solar Radiation dedicated to calculate the solar radiation components on the surface. This module can be found in the Spatial Analyst extension of the program. As the global radiation is determined by many factors, the module contains various setting options.

One of the most important factors is the aspect and slope derived from the characteristics of the surface. This kind of information can be obtained from the input DEM. Thus in the next steps the surface parameters can be taken into consideration in modeling global radiation.

The Solar Radiation model can elaborate estimations for point and area features. Converted into real coordinate system the program recognize the geographical latitude of the area even at the moment of loading the DEM, furthermore the inclination angle of solar radiation can be determined. In the case of point-wise estimations the location of the point must be specified. In our case, the location of Kosice airport meteorological station is introduced. The next step contains the time settings. The most important parameter is the sequence of the day in the given year. Based on this parameter the inclination angel of the radiation, the way length of solar beam in the atmosphere and the astronomical duration of sunshine can be determined. All these parameters of radiation presented above can be calculated exactly.

In the following step the input parameters refer to the atmospheric conditions like cloud cover, humidity, opacity etc. In the radiation parameters module two values can be adjusted, namely the proportion of diffuse radiation and the transmissivity of the atmosphere (τ). In this study the values of proportion of diffuse radiation was taken from the PVGIS dataset (http://re.jrc.ec.europa.eu).

In the case of the transmissivity of the atmosphere (τ) the default value of the modul is 0,5 for a generally clear sky. During the experiments turned out that the model is very sensitive to this parameter. The transmissivity of the atmosphere highly depends on the actual state of the atmosphere influenced by the characteristics of the dominant air masses; in this way this value is determined by the weather situation.

Parameterization of transmissivity of the atmosphere

The aim of this part of study is to find the approximate τ parameter of each radiation situations described by the measured global radiation values. The monthly radiation values are classified in function of standard deviation (σ) into three categories, namely M±σ interval concerning situations with average radiation values, M+2σ for situation with high values and M-2σ interval including the situation of low global radiation. In case of some months there are more categories meaning very low or very high values (M±3σ). In order to determine a monthly τ parameter an approximate τ was determined for each category weighted with the number of cases of the given category. In this way an empirical τ parameter was calculated separately for each month (Table 1).

Table 1. Radiation parameters: the proportion of diffuse radiation in % (Diff/Dir) (Source: PVGIS European Communities, 2001-2010), transmissivity of the atmosphere (τ) – calculated value

	Diff/Dir	
January	0.68	0.32
February	0.61	0.37
March	0.55	0.44
April	0.53	0.43
May	0.52	0.48
June	0.55	0.43
July	0.50	0.38
August	0.52	0.41
September	0.51	0.46
October	0.52	0.39
November	0.66	0.48
December	0.71	0.44

In the next step point-wise estimations are elaborated for the location of Kosice setting the input radiation parameters to the calculated τ coefficients and to the Diff/Dir proportion taken from the literature. The investigated period is divided into monthly intervals, in this way global radiation data are calculating by modeling for 12 periods. This values are compared then with the measured ones in the same point (Kosice) and also compared with the modeled value with the default τ parameters (0,5 for) of ArcGis Solar Radiation module (Fig. 1).

The accuracy between the modeled and measured value is quantify by RMSE characterizing the whole period with an error of 17.8%. The difference between predicted and real radiation values in seasonal breakdown are the next: winter 11.47%, spring 25.11%, summer 4.01% and autumn 6.07%.

It can be considered that in the case of few seasons the corrected τ parameter yields very small errors (summer and autumn). In other cases the magnitude of the error is still large; in these cases further enhancing procedure of τ can lead to higher accuracy of the results. On possible factor which can induce inaccuracies is the fact that this parameter is strongly linked to the weather situations [2] not analyzed in this study. In the forthcoming analysis related to this topic this factor must be investigated.

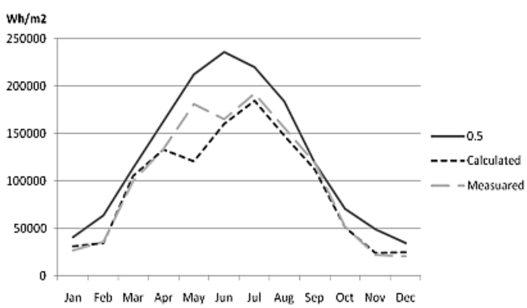

Fig. 1. Monthly sums of global radiation (Wh/m^2): calculated with the model parameterization, calculated with corrected τ and measured values

Results

Based on the method described above a spatial simulation is elaborated (with corrected τ parameter). As the result a high resolution global radiation map is created. It should be point out that this kind of calculation is very time-consuming using classical calculations. The simulation of our map takes about 10 minutes.

Fig. 2. shows the radiation map of the study area for the summer period. The statistics of the corrected map are: AVARAGE 500905 Wh/m^2, MIN 438173.4 Wh/m2, MAX 562638.3 Wh/m^2, and STANDARD DEVIATION 11169 Wh/m^2.

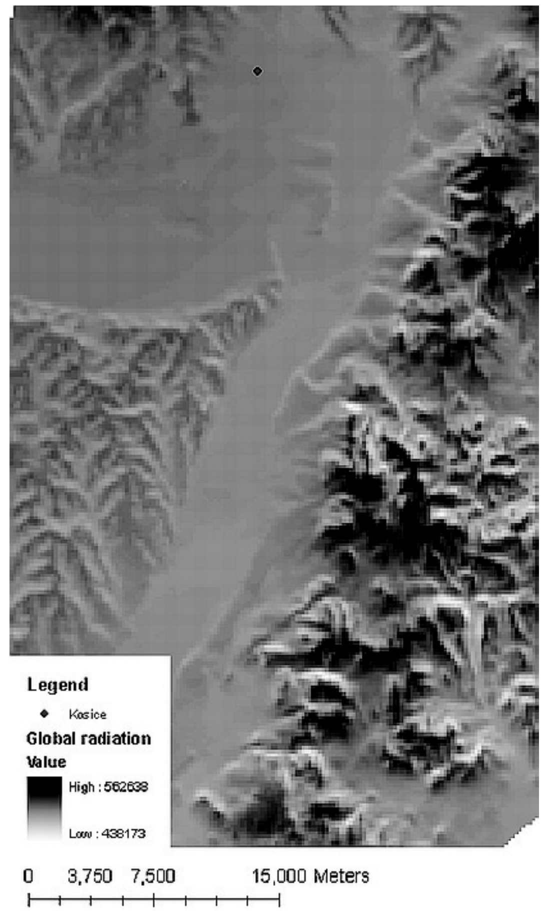

Fig. 2. The corrected global radiation map for the summer period of Hernad-valley (Wh/m^2)

Conclusions

In this study the errors of global radiation map modeled in GIS is quantified. We consider that GIS environment is very useful for this kind of investigations, because the characteristics of the surface and the astronomical factors can be taken into consideration with high accuracy. In the other hand the model is very sensitive to the atmospheric parameters, thus the parameterization could produce results very different from the measures values in case if it is not validated with real situations. Unfortunately very few radiation measuring station are located all over the country, thus precise methodological enhancement is required for modeling.

This study shows the fact that the accuracy of atmospheric transmissivity parameterization influences significantly the final results. In the case of default parameterization of the model the RMSE between the modeled and real value is 30,02%, but using the corrected τ parameter this error decreases to 17,81%.

The high resolution global radiation maps gives essential information for renewable energy source applications, but in same time are very useful in ecological, forestry interventions too. On the regional level the interpolation methods of point wise measurement can not establish sufficient high resolution regarding spatial and temporal distribution of global radiation, in this way the developments of this kind of GIS modules are necessary.

Acknowledgement – The authors would like to express their thanks to the OTKA (Hungarian Scientific Research Fund, program: K 75794) for support of the research.

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Wind Energy, the Energy of the Future for Romania

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The wind energy, the energy of the future for Romania, brings to the attention of specialists in the energy field the imperative and urgent necessity to provide and use new sources of energy instead of conventional ones, fuel-based. In the current context, characterized by the alarming increase of the pollution, reducing dependence on these fuels is more and more important. The wind energy proved to be an ideal solution for the world energetic system. Through its particular way of generation it leads to the decentralization of the sources, which in turn lead to a new development model. The wind energy is among the forms of renewable energy which is suitable for small-scale applications. The main advantage of this type of energy is that emissions of pollutants and greenhouse gases are zero. Other advantages are: it produces no waste; the production costs per unit energy (kmh) are reduced. According to several studies, among which PHARE, Romania would have a wind potential of about 14,000 MW power installed, respectively 23,000 GWh electric energetic production per year. For this reason we consider that the wind energy with other forms of unconventional energy would be the energy of the future for Romania.

Keywords: wind energy, renewable energy, energetic system, pollution, greenhouse effect

Introduction

In the recent decades, more than ever, non-conventional energy sources (ecological), which could not be exploited so far, are major concerns for both scientists and those involved in economic sectors (particularly in the energy sector).

And this for three reasons, namely:

- on the one hand, energy resources are limited;
- energy industry based on conventional fuels is the most polluting that generates greenhouse gases and thus contributes substantially to global warming;
- on the other hand, in order to ensure sustainable development that future generations will benefit of energy sources.

According to the European Wind Energy Association, Romania is among the top ten

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largest wind parks in Europe, it has the chance to occupy the first place in the top if the Czechs from CEZ carry out the 1.1 billion euros investment plans in the wind park from Fântânele and Cogealac villages of Dobrogea.

Among non-conventional energy sources (solar, wind, marine, geothermal, etc.) the wind is even from ancient times a natural source exploited by moving the windmills to the most modern wind aggregates that exploit the wind energy potential (Fig. 1a. and Fig. 1b.).

Fig. 1b. Wind park with modern aggregates

Wind parameters. Theoretical aspects

To choose the locations to dispose wind aggregates, studies, researches and analysis of wind parameters are necessary. The wind is a vectorial meteorological element, highly variable in time and space. Within the general circulation of the atmosphere, it is conditioned by the baric horizontal contrast. The horizontally displacement of the air is called wind or advective motion.

The movement of the air currents from one place to another is determined mainly by the development of various baric systems and by the activity of the major centers of action. The wind is characterized by two elements highly variable in time and space: the direction of the wind, which is determined in relation to the cardinal point from which it blows and the velocity. In order to indicate wind direction we use the wind rose with the four cardinal points and with the four or twelve intercardinal directions. The velocity represents the distance traveled by air particles per time unit, expressed in m/s. (Bâzâc, Gh. 1981).

The wind is the most frequent form of air movement in the horizontal plane, while the atmosphere is made up of volumes of air with different characteristics in terms of heat and pressure as it always tends towards equilibrium by the vertically or horizontally displacements of air.

In the atmospheric layer, of friction (from the ground), the wind velocity has a daily walk, with a maximum at noon and a minimum at night to the morning. In higher layers, over a few hundred meters, the diurnal variation of wind velocity is the inverse of that in the lower structures. The highest velocity is observed during the night, and the smallest around noon hours.

The cause of the different daily walking of the wind velocities in relation to height is the diurnal variation of the intensity of the vertical turbulent exchange in the atmosphere. During the day, the high velocities in the upper layers are transmitted in the lower ones through the turbulent and convective exchange. In Romania, the wind regime is determined both by the general atmospheric circulation features, as well as by those of the active surface, obviously the role of orographic barrier of the Carpathians, which determines through orientation and altitude a regional and local air circulation.

The productivity of the wind motors is highly dependent of the high wind frequency, relief and their geographical position, which leads to a careful analysis of the hourly, monthly, annually and seasonally average values and the likelihood and assurance of producing various wind velocities.

Based on the data about the wind and the research, from a geographical point of view, the region of Romania with the highest wind potential is located in the East of the country, including the mouth of the Danube Delta and the Romanian Black Sea Coast, the Plateau of Moldavia and Dobrogea, insufficiently exploited in practice (Fig. 2).

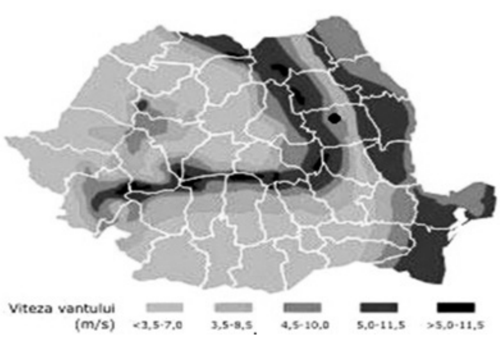

Fig. 2. Map of Romania with the distribution of the average velocities of the wind (Source ANM Bucharest)

The charts below support the above assertion, showing the frequency of the average annual velocities on directions, calculated based on data from five weather stations for a period of 40 years, starting in northern Moldavia and till the Black Sea shore (Fig. 3 a, b, c, d, e). (N. Rusan, 2008, 2010).

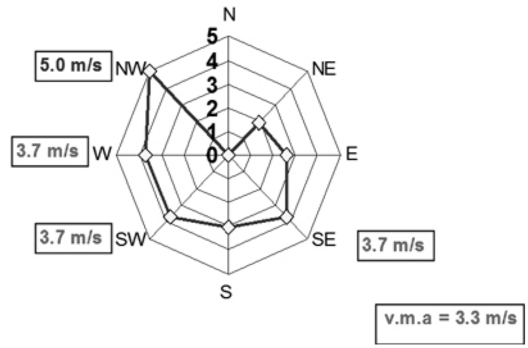

Fig. 3a. Average annual velocity of the wind on directions in Botoșani

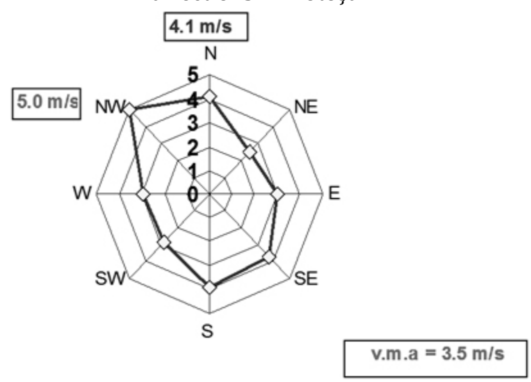

Fig. 3b. Average annual velocity of the wind on directions in Iași

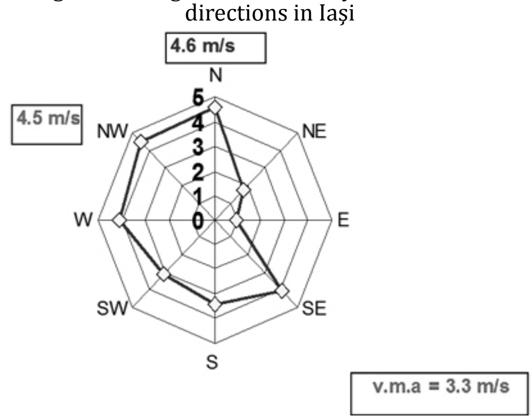

Fig. 3c. Average annual velocity of the wind on directions in Bacău

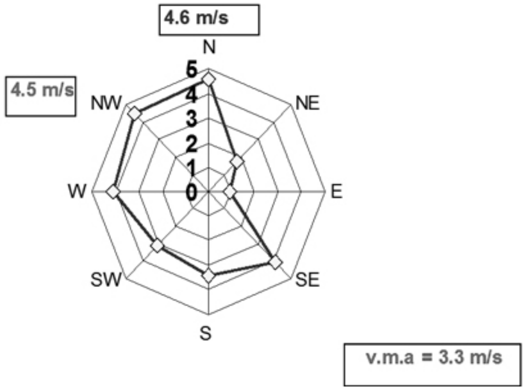

Fig.3d. Average annual velocity of the wind on directions in Galaţi

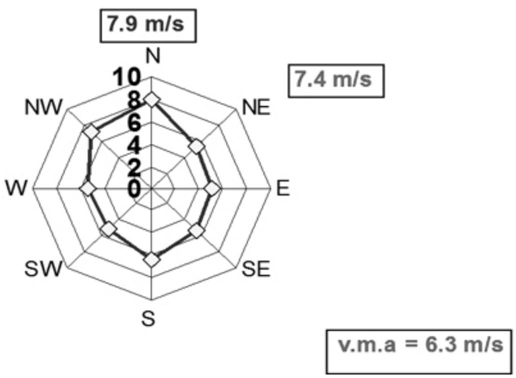

Fig. 3e. Average annual velocity of the wind on directions in Sulina

Fig. 3a-e. The average annual velocity of the wind calculated with data from the meteorological stations from the south-east of Romania

The situation of the wind parks in Romania

Within Romania's energy strategies, wind energy separated prominently. If in 2010, the energy produced by other sources than the wind lacked the positive news, the unconventional energy balance was noted as an excellent one by the installation of 200 wind aggregates.

According to a PHARE study, Romania's wind potential is about 14,000 MW installed power, i.e. 23,000 GWh of electricity production per year. This is the total potential. Considering only the technical and economic potential that can be arranged for about 2,500 MW, the corresponding electricity production would be around 6,000 GWh per year, which would mean 11% of total electricity production of our country.

Romania has the highest wind energy potential in South-East Europe. A study made by Erste Bank locates Romania in the second place at the European level, regarding the ideal location to build a wind park. According to the national strategy for energy resources exploitation in 2003, until 2015, in Romania should be put into service wind parks with capacities of 280 MW each and a total capacity of 3000 MW, or approximately 1,500 wind aggregates (cf. AREE).

The biggest investors in this sector for the projects in Romania are the CEZ from the Czech Republic and ENEL of Italy.

Currently in Romania, the largest wind parks are at Fântânele-Cogealac, with an installed power of 300 MW, followed by the Cernavodă wind park with an installed power of 138 MW, both in the county of Constanta (Fig. 4a-b.). Also in Dobrogea, other wind parks of smaller power are in Peştera locality with an installed power of 90 MW (Fig. 5.) and on Nucarilor Valley with 38 MW, both in the county of Tulcea. Locations on the land of Romania, in which wind parks are posted of different capacities are in Bacău County at Pânceşti, with a single turbine whose installed power is 250 kW. Another wind park is in Semenic Mountains, in Caraş Severin County, where four wind aggregates are assembled, even before 1989, with a total power of 1200 KW at Ploieşti, in Prahova County, with a capacity of 660 KW; another wind aggregate is in Tihuta Pass in Bistriţa Năsăud, with an installed power of

250 kW and Tureni, Cluj County. On the map of Romania, the locations of sites for wind aggregates are quite different in relation to the potential we have in terms of average wind, which is used in energy studies (Fig. 6.).

Fig. 4. Aerial photographs with turbines locations at Fântânele (Source: Images produced by EDPR)

Fig. 5. Aerial photograph with turbines location at Peştera locality (Source: Images produced by EDPR)

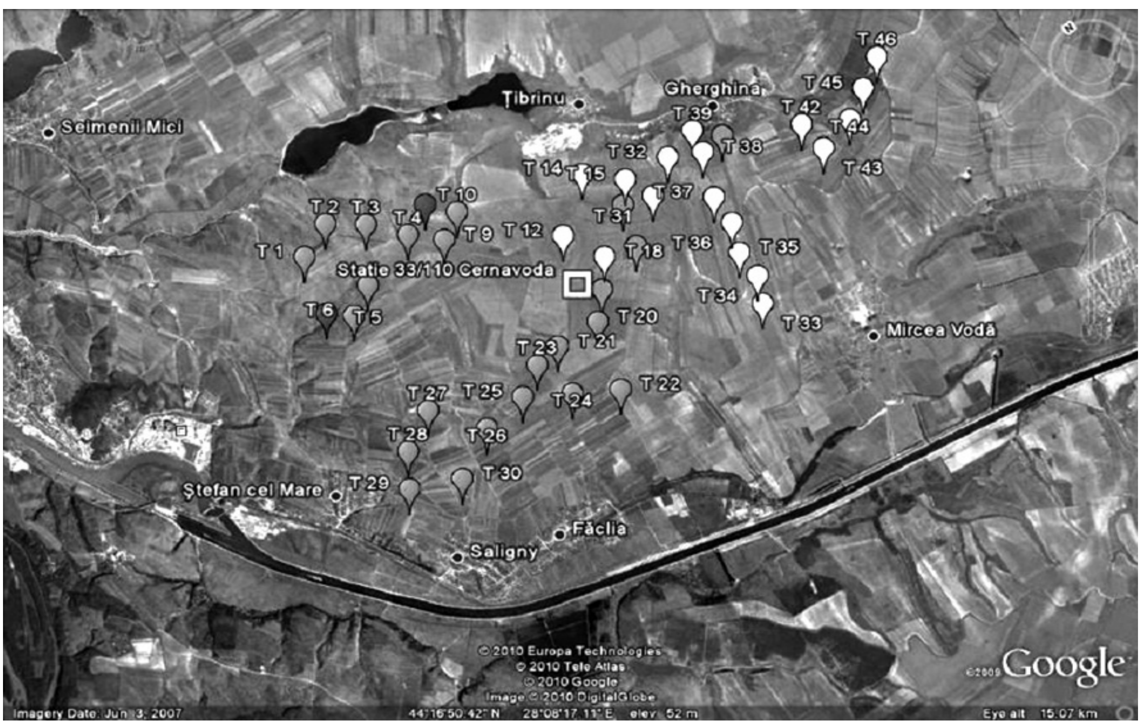

Fig. 4a. Aerial photographs with turbines locations at Cernavodă (Source: Images produced by EDPR)

Fig. 6. Map of Romania with localities in which wind aggregates are posted

The perspective of developing new projects in the wind energetic domain

In Romania, until 2020, a total of capacities in renewable energies of 4,800 MW will be installed, of which 70% will be wind energy.

Areas like Galaţi, Vaslui, Vrancea, Brăila or Iaşi attract now the investors in wind energy, after the counties Tulcea and Constanţa have held the frontlines of such investments in recent years.

According to the Transelectrica data comprised in the perspective plan of the electricity network of transport in 2008–2012, except the counties of Tulcea and Constanţa, where until now there were about 75 possible projects registered, the following preferred destinations by the investors in the wind segment are Galaţi, where they could do about 11 projects, Vaslui, with 10 wind projects, Vrancea with seven such projects, Brăila, where there is an intention expressed by many investors to achieve six wind projects, Iaşi, where they study to achieve four projects. At Întorsura Buzăului in Covasna County projects were performed for a wind park with a total of 60 aggregates, 20 in the first two years. In south-western Romania, at Orşova, investors have also executed projects for the installation of 50 wind aggregates.

Specialists in the field say that there are three important factors that matter a lot in choosing a location to invest in wind energy. Firstly there is the wind that matters; it must have a high frequency and velocities of more than 3 m/s in order to trigger a wind aggregate and from this point of view the best areas are Dobrogea and Moldavia. Secondly there is the possibility to connect to the electricity network that counts, and here Dobrogea begins to lose attractiveness due to numerous projects for electricity production, not only on the wind segment, and the network of reception which does not allow the development of large projects.

Advantages

Unlike other energy sources, the power of the wind is inexhaustible, does not pollute the environment and does not relieve emissions that lead to acid rain production or to the amplification of the greenhouse effect. Wind energy benefits from one of the cheapest technologies of production, with costs between 4 and 6 eurocents per kilowatt/hour.

Wind turbines can be built near farms, improving the economy in the rural areas where the wind intensity is higher. Also it doesn't affect the farmers' activity because it occupies a relatively small surface.

One of the biggest advantages of these generators is their longevity, without large additional investment from the time of installation.

Disadvantages

To be successful, wind energy must be close to the price of conventional energy. But in this case, the price competitiveness depends on the activity of air masses in that area. Even if in the last decade the cost of wind power production has decreased, a bigger investment is needed in this area than in power plants. To become more profitable we have to finance development projects for the production technology. The big disadvantage is that wind does not have a continuous activity and therefore it cannot provide energy all the time. And the wind power cannot be stored and used when needed, as the solid fuels. The areas with intense wind activity are usually in isolated places far from the cities, where the wind energy is needed. Despite the fact that the wind plants have a limited impact on the environment when compared with other types of plants, there are complaints because of the noise produced by the propellers, the aesthetic effect, but also due to the birds that die on the impact with the propellers of the generators.

At present, these problems have been corrected or greatly reduced by the technological progress or the better positioning of plants.

We believe that the use of wind energy remains a priority of the present and the future for Romania.

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The Regional Extrapolation of Wind Speed in the Hernád-valley

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The Department of Meteorology at University of Debrecen started a research project (OTKA K 75794) in 2009 in Hernád-valley in order to examine climatic and socio-economic conditions with the aim, that we establish what kind of potential are at disposal of the area concerned to wind-, solar energy and to utilization of biomass. We measure expedition-like the characteristics of the airflows on 2 altitude levels in a measurement tower, which set up in the northern part of the valley, in border of city of Hidasnémeti. We demonstrate that the topographic feature how influences the spatial distribution of the wind speed based on WINDSIM model.

Keywords: wind resource assessment, North-East Hungary

Introduction

The aim of the study is to present our results in wind resource examination in north part of Hernád-valley in Hungary. Our research project object is that collect information about characteristic of wind energy and other weather-depend energy resources (solar energy and biomass) in order to help renewable energy project development in this area.

The wind power the success of utilisation it depends, how we know the wind power potential standing for the provision before the starting of the investment

The wind power is especially sensitive to the geographical situation of the place, the position of the surrounding relief elements, obstacles, the roughness of the surface and onto somebody else other characteristics. Our aim, that let us give guiding from that direction, that based on the characteristics of the wind influenced by the topographic features the Hernád-valley which areas of his may be suitable wind power onto the placement of utilising equipments.

Datasets and methods

Research area

The valley of the Hernád River is our research area, which runs from north-east to south-west direction between Cserehát

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and Eperjes-Tokaji Mountain. This valley has a natural contact between the ranges of a Northwest-Carpathian mountains and the Great Plain. Based on his geographical situation and his relief conditions we presuppose that he gives a natural route for air masses arriving from north-east and takes a part in the local ventilation going on between the mountain range and flatland areas [1].

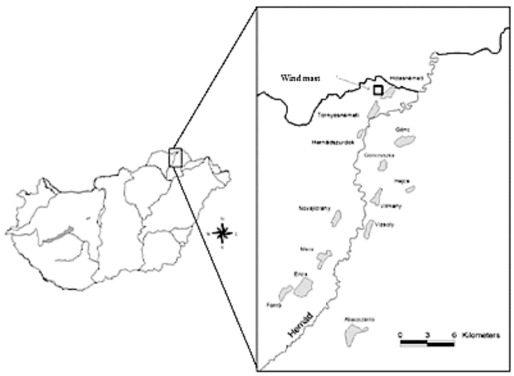

Fig. 1. Geographical situation of the research area in Hungary

Climatic dataset

Onto the aim of the wind climatology research was built up a 20 m tall wind measurement tower on northern part of the Hernád valley. We placed on top of the tower sensor for wind direction and 2 anemometers on 10 m and 20 m level. The station is located 500 m west from Hidas-németi city on a smaller hill. Geographical coordination was north latitude 48°30', east longitude 21°13', and 173 m above sea level.

We used to the model's running a 8 monthly periods 10 minute wind speeds and wind direction measured data between April 23 and December 5 in 2010. The data covering of the period was 90% percent. Data deficiency was in June and end of November. The cold winter weather influenced the function of the sensors in this period.

WINDSIM model

To the utilisation of the wind power we have to know the features of potential standing for taking action on an area. We may collect information about this with the measurement of the wind speed. If we make the measurement on one level, we may calculate the expected power generation with a big mistake, because we have to make vertical and horizontal extrapolation to found best place for wind turbine. The numerical methods help to solve this problem.

We compared it already in our earlier examinations [2], that what kind of principles doing the regional extrapolation of wind speed data. Above the surface have collectively influenced the velocity of streaming air by the exterior and inner friction, the topographic features, roughness of the surface and surface artificial obstacles. If the effect of the topographic features is negligible, then the roughness change admitting inner boundary layer models give a good solution (for example WAsP model). In terms of the turbulence a dynamic approach may be more suitable in case of sites with complex topographic feature.

We applied to examination of wind resource of Hernád-valley the 5.0 version of WindSim model. The wind farm design tool based on CFD (Computational Fluid Dynamic) analysis. It developed by Norwegian VECTOR AS. WindSim is based on a 3D Reynolds Averaged Navier Stokes (RANS) solver [3], [4]. The name of this original softwer is PHOENICS. Solving the non-linear transport equations for mass, momentum and energy makes WindSim a suitable tool for simulations in both complex terrain, and in situations with complex local climatology.

The model with a modular construction the average wind speed influenced by the topographic features gets in more stair to a spatial distribution, that the selected wind power defines the expected power generation of utilising equipment in a final result.

The Terrain module generates a 3D model of the area based on elevation and roughness data. The Wind Field module simulates how the terrain affects local wind conditions in terms of speed-ups, direction shifts, and turbulence. Placement of turbines and measurement points is done in the Objects module. The Results module allows easy inspection of flow variables such as wind speed, directional shifts, turbulent intensity, and the vertical component of the wind. The wind resource map is established by weighting the wind database against measurements. The wind resource map is the basis for the energy optimization. The Energy module is where calculate the annual energy production (AEP) for each turbine within the wind farm. Practical aim is, that planned wind power plants get optimal place in terms of the wind potential.

Digital terrain model

The initial points to run WindSim model is a digital terrain map. In the first section of our research we used a terrain model from SRTM (Shuttle Radar Topography Mission) database which prepared in February of 2000 by NGA (National Geospatial-Intelligence Agency) és a NASA [5].

The grid resolution of terrain model was 90 m x 90 m. We used to our research xyz format data which show on Fig. 2.

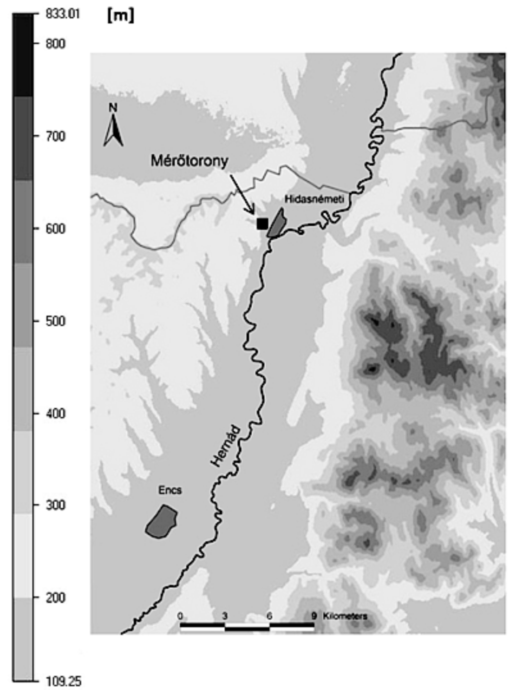

Fig. 2. Digital terrain model of the research area

Results

It was probable already before the starting the climatology examinations that the river valley influences the airflows. North part of Hernád-valley the most frequency wind direction was north and the opposite, south direction (Fig. 3a.). We found smaller frequency by western direction because of Cserehát region and the eastern direction where the Tokaj-Eperjesi Mountain has an effect on the wind direction.

The wind speed is the largest one in case of a northern-northeast direction and southern-southwest direction according to the orientation of the valley (Fig. 3b.). In this direction the wind speed reached 4.5 m/s on 20 m above surface in 2010.

The prevailing wind direction was north (when wind blow from Kassa) according to frequency and average wind speed of direction sectors. We may establish that Cserehát does not considerable obstacle in case of northwest and northern direction wind, the modelled wind speed gradually decreases moving into southern direction in the river valley (Fig. 4a.). The higher wind speed connects to the taller mountain peaks near Vilmány and Hejce. The range of modelled wind field higher when wind blow from south direction (Fig. 4b.). The wind speed strengthening above mountain, but stay windless surrounding of Hidasnémeti. The wind speed appears considerable moderating in case of winds with an eastern direction really.

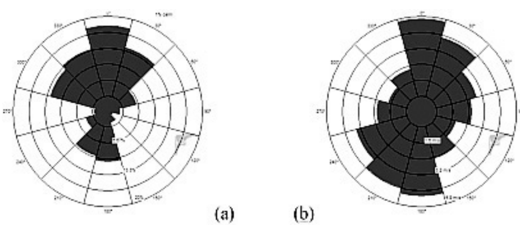

Fig. 3. Frequency distribution of wind direction (a) and average wind speed by wind direction sectors (b) 20 m above surface in Hidasnémeti

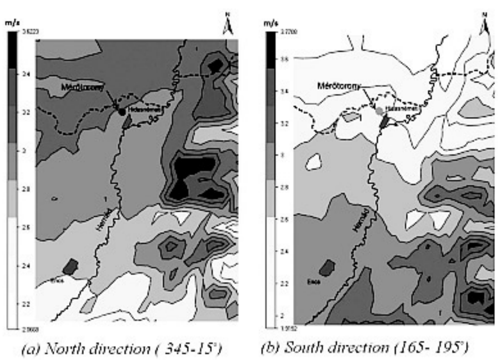

Fig. 4. Modeled wind speed field when wind blow from north (a) and south (b) direction

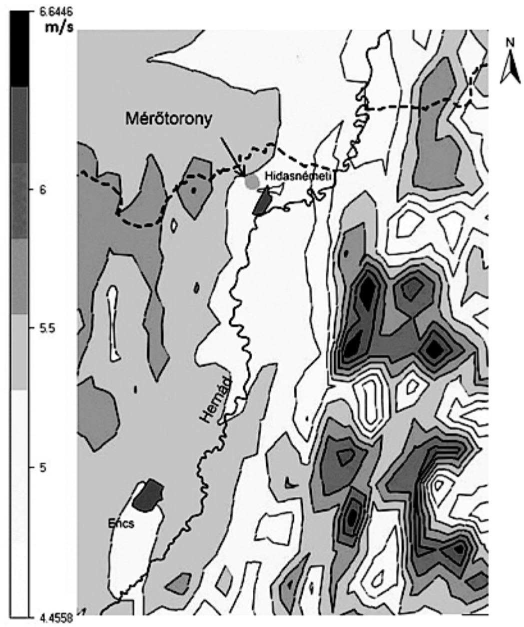

Fig. 5. Modeled wind speed field 50 m above surface in Hernad-valley in Hungary

We present on the Fig. 5. the wind resource map of Hernád-valley in 50 m above surface based on WindSim model. The valley of the Hernád river is moderation windy. We found that may be suitable for utilisation of wind energy the Cserehát region and his eastern forefront, and southern area of the valley.

Conclusions

We see that WindSim 5.0 software package suitable to wind resource assessment of Hernad-valley and his wider environment and to accomplish our research objectives.

In the first section of the research we used more simplification to create wind resource map. We plan that in the future to use more accurate digital terrain model and more climatic information to WindSim model.

Acknowledgements – This work was supported by the Hungarian Research Fund, OTKA K 75794 research project.

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Collegium Geographicum 8. Special Edition, 2011

The Influence of Pitch Control on Working Parameters of Cross-flow Turbines

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A characteristic feature of cross-flow turbines is the strong fluctuation in the circumferential force that generates axle power, because the interaction between the blades and the medium is not constant. Due to this varying interaction, the force that occurs on one blade (and its tangential component) fluctuates cyclically as the blade changes its position. In other words the circumferential force depends on the parameters of the flow, inclusive of the pitch angle of the blades. The paper shows the effect of pitch control in comparison with the condition, when the turbine works with fixed blades.

Keywords: Wind turbine, pitch-control, angle of attack

Introduction

Small vertical axis cross flow wind turbines (VAWTs) with straight, fixed pitch blades parallel to the rotation axis and located along a cylinder, have at least two serious disadvantages. These are their poor starting torque and quite poor efficiency. Without a variable blade (i.e. there is not blade pitching motion, see Fig. 1.) it is difficult to reduce the effect of these drawbacks. In spite of the fact that neither simple, nor effective pitch control system has been shown, it is reasonable to analyze theoretically the effect of pitch control on the working parameters of the straight baladed cross flow turbines. This paper briefly summarizes the effects of the variable-angle blade on the characteristics of the leading velocity triangle and, in turn, on the tangential force that generates axle power.

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Main problems with fixed pitch VAWTs

Poor ability to self start

With no variable pitch, the only way to improve the starting torque is using cambered blade profiles (i.e. "curved" profile, see the illustration in Fig. 2.), but the starting torque can only be marginally improved and it probably remains insufficient to overcome drive train friction for self-starting.

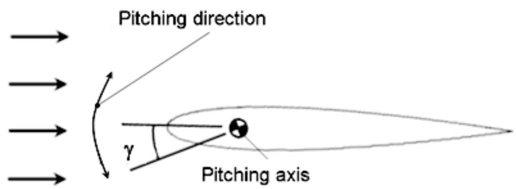

Fig. 1. Blade pitching motion

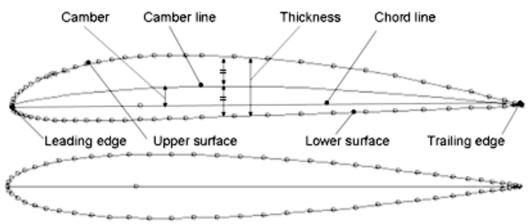

Fig. 2. Airfoil nomenclature
Above: a cambered profile
Below: the same profile without camber (symmetrical profile)

Based on data from Refs. [1, 2] it can be determined that a high blade chord Reynolds number (Re) improves blade (static) stall angle as shown in Fig. 3., reducing the tendency to stall and thereby improving self-starting. The proper blade chord Reynolds number can be maintained with solidity, where solidity is equal to (number of blades)*(length of blade chord)/(impeller radius), i.e. solidity = n*c/r and Re = Vc/ν where V is relative flow velocity experienced by blade and ν is the kinematic viscosity of the medium and it is approximately constant. Thereby high Re requires large chord (c) and (or) high blade velocity V. Large chord increases solidity and improves self-starting (Ref. [3]). But increasing cord length (c) does not solve the problem. To increase V, tipspeed ratio (i.e. the ratio of blade tangential velocity to ambient flow velocity (λ)) must increase, which will only happen if solidity is reduced by reducing c, which in turn reduces Re, or by reducing the number of blades (n). Fixed pitch turbines with low solidity produce very low starting torque.

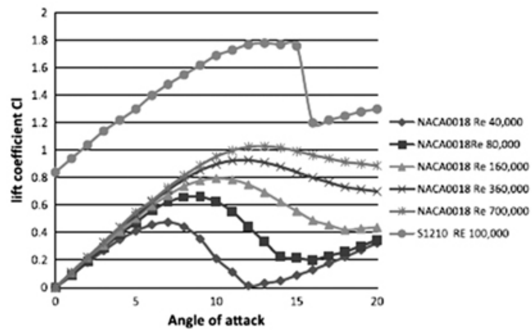

Fig. 3. Re-number and camber effects on (static) stall-angle (Refs.[1, 2])

Poor efficiency

Large, low solidity wind turbines have achieved a measured peak Cp (performance coefficient or power coefficient, i.e. the ratio of shaft power out to kinetic energy flux in swept area) up to about 40% at λ about 5 or more, where blade stall does not occur [4], but their solidity is low, which yields poor ability to self start. VAWTs with a large number of blades can even out torque fluctuations, however having more blades of a given chord length means higher solidity, lower tipspeed ratios and lower efficiency. Smaller chord length results in lower blade chord Reynolds numbers and poorer blade performance (Fig. 3.).

Using a variable pitch control system, turbines do not suffer from the above mentioned problems so much, because an active pitch control system can generate higher starting torque and higher efficiency.

Leading velocity triangle in case of variable blades

Reference [5] analyzes the characteristics of leading velocity triangles in detail for cases $\lambda < 1$ and $\lambda > 1$. It can easily be seen that velocity triangles will not change with variable blades.

Therefore, it remains true that the extent of the changes in the direction of the relative velocity (w), which changes cyclically as a function of the rotation angle of the impeller (Θ), will increase with the tipspeed ratio, and the fluctuation in the angle of attack (AOA, see Fig. 6.) will decrease. In case of variable blades, the following changes: the angle of attack on the blade (δ , i.e. the angle between the velocity vector w and the blade chord) will not be the same as the angle between the tangential and the relative velocity vectors (β), but will differ from it by an angle of $\pm \gamma$, according to the blade angle (Fig. 4.)

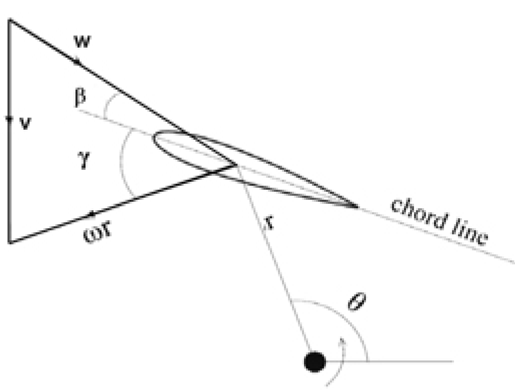

Fig. 4. Leading velocity triangle in case of a variable blade

This will, of course, affect the nature of dependence of tangential forces on the tipspeed ratio. The nomenclature of forces are summarized on Fig. 5. and Fig. 6.

Fig. 5. Symmetric airfoil with zero lift

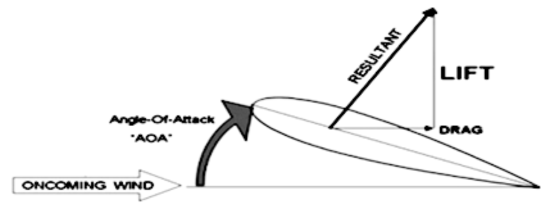

Fig. 6. The chord line is an imaginary one between the leading and trailing edges; it is used for setting Angles-Of-Attack. When the AOA is not equal to zero, then the resultant force is equal to the vectorial sum of the drag and the lift (symmetric airfoil)

The angle of attack in variable blades

Changes in the angle of attack (i.e. the δ angle between the velocity vector w and the blade chord) as a function of the Θ angle (with the tipspeed ratio as parameter) assuming a VAWT with blades parallel to the rotation axis and located along a cylinder :

$$\delta(\Theta) = arctg \frac{sin(\Theta)}{\lambda + cos(\Theta)} \quad (1)$$

In this case, the blade chord is parallel to the tangential velocity vector, and the angle setting of the blades is $\gamma = 0°$.

Due to the geometrical conditions, the angle of attack (i.e. the δ angle between the velocity vector w and the blade chord) will as a function of the Θ angle, fluctuate to a less and less extent as the tipspeed ratio increases [5], thus the tipspeed ratio λ has values, with which the lift to drag ratio is close to the optimum value in a relatively wide range of the Θ angle.

The above-defined optimum range of the tipspeed ratio λ can be made wider, as (1) takes the following form if assuming variable blades:

$$\delta(\Theta) = arctg \frac{sin(\Theta)}{\lambda + cos(\Theta)} \quad (2)$$

This formula assumes the angle setting of blades is variable in a general sense, i.e. the angle setting is not only an additive constant, but may change as a function of the blade position. Of course, the number of blades (n) significantly affects the operation of the machine. The formula (2) applies to every single blade of the machine. In the formulae (2) as applied to each blade, the angles Θ of the blade positions differ from each other in blade spacing.

Therefore, the function γ(Θ) also has the same form for every blade, and the values of the variable Θ will differ from each other by the blade spacing for each blade.

Variable blades allow for an optimization of the operation

We illustrate the possibilities of variable blades with the following examples.

In our first example, the velocity parameter is smaller than unity (λ<1). In this case, a VAWT may be made to operate as a Savonius rotor. In this case (λ<1), the tangential velocity approximates the velocity of the medium from below. If the blades are not variable (with a fixed angle setting of e.g. γ=0°), its operation is virtually precluded. Let us assume that the blades of a machine with n=3 blades are variable. Furthermore, let us assume that the angular velocity of the impeller is ω and the function γ(Θ) generates a rotation of an angular velocity of ½ ω against the impeller's rotation for each blade. The phase is selected according to the direction of attack (Fig. 7.). In the figure, an asterisk indicates the leading edge of the blade under study in the Θ = 0° position.

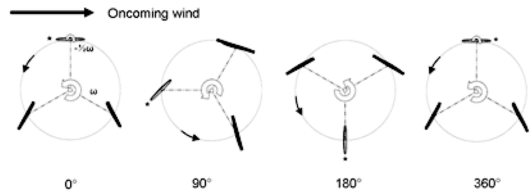

Fig. 7. With variable blades and λ < 1, a VAWT with blades parallel to the rotation axis and located along a cylinder can operate as a Savonius rotor

The series of pictures to illustrate the phases of movement makes it easy to understand that such an operation is possible. It is made possible by an appropriately selected γ(Θ) function via the shape drag that changes with the angle of attack (Fig. 8.).

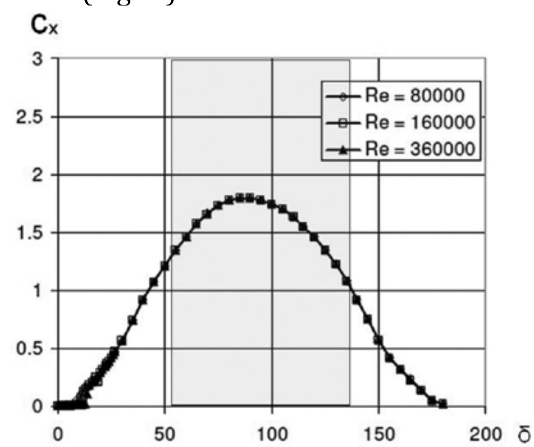

Fig. 8. With variable blades and λ < 1, the individual blades operate in a wide range of the angle Θ, in positions resulting in either a high drag (approx. the greyed range) or a low drag (the picture shows the Cx (drag) curve of the NACA 0012 symmetrical profile)

The next example illustrates that having variable blades allows extending the range of the Θ angle that corresponds to angles of attack that result in a high lift factor near stalling for the individual blades. This is important, because only a very narrow range of the δ angle (between the velocity vector w and the blade chord) will yield such an advantageously high lift factor (Fig. 9.).

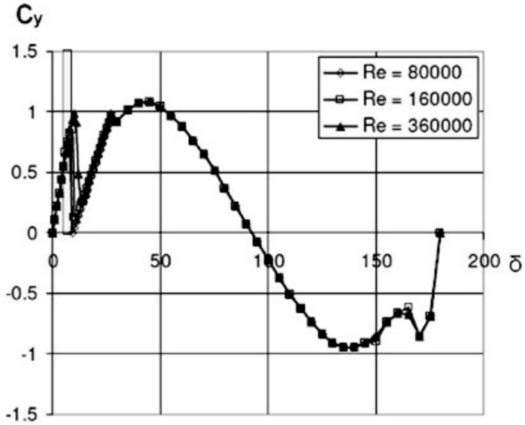

Fig. 9. Having variable blades allows such a high lift factor in a wider range of the Θ angle, which would otherwise be present only in a very narrow range of the angle of attack (approx. the greyed area). The picture shows the Cy (lift) curve that corresponds to the NACA 0012 symmetrical profile.

Conclusions

The analysis in the article shows that optimization possibilities of the operation of a VAWT can significantly be enhanced by means of using variable blades. Variable pitch designs can theoretically achieve any desired pitch regime and hence any desired angle of attack for maximum efficiency. We have shown that, by using variable blades, the range of parameters, in which the machine can remain in motion, can be expanded. The prerequisites to remaining in motion and starting without external aids have, however, been not clarified. Therefore the next part of our work will deal with these problems.

A similarly important question is the range of stable operation. When an airfoil experiences an oscillation in the angle of attack in which it goes beyond the static stall angle, dynamic stall may be present. This means that several subsequent different phenomena take place, with a complex overall behaviour of the airfoil loading, yielding aerodynamic forces very different from those obtained in static conditions.

Because of the rotation of the blades around a vertical axis, the angle of attack changes in each period, and the variation of the angle of attack has a sinusoidal form. The zero value of the angle of attack occurs when the position of the blade yields zero lift:

$$\tan[\delta(t)] = \frac{\sin(\Theta)}{\lambda + \cos(\Theta)} \qquad (3)$$

in which δ (t) is the function of time of the angle of attack and ω is the angular velocity. The actual value of δ is in relation to the actual position of the blade (Θ) as follows:

$$\delta(t) = \delta_{max} \sin(\omega t) \qquad (4)$$

In a rotational frame of reference fixed on the turbine blade, the blade would undergo a cyclic variation in the effective medium velocity and the angle of attack. The variation of this angle of attack is very similar to what would be experienced with a sinusoidally pitching motion of a blade in a stationary frame of reference. On the basis of this similarity, it is likely that there is a similarity in the dynamic stall phenomenon for these two types of motion. Thus the investigation into the dynamic stall in case of relatively simple oscillating airfoils can provide us with remarkable results as to what would occur in case of a real but more complicated VAWT blade. These problems have many sub-problems as well, the research of which will also form part of our work.

Acknowledgements – "The described work was carried out as part of the TÁMOP-4.2.1.B-10/2/KONV-2010-0001 project in the framework of the New Hungarian Development Plan. The realization of this project is supported by the European Union, co-financed by the European Social Fund."

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New Wind Power Turbines – Generation 2

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The paper presents a new concept of modular new wind turbines capable to fully collect the wind energy from the rectangular surface of a 3-12 m width and a height depending on the turbine power. The variation of the wind speed with the height is not affecting the efficiency of the new wind turbines and the power may reach 20 MW.
The investments corresponding to electric power output in the wind power with new wind turbines – generation 2, are reduced by 50%, and the operating period of new wind turbines is increased as the air stream speeds at which they can operate are much larger than with the classic wind turbines. Moreover, the new wind power turbines need not be installed on a high pillar, the distance among them is smaller. By the use of the new wind turbines, the surface of the wind power area economically operational is also increased.
The electric energy generated by a new wind turbine park – generation 2 is 100 times higher than the electric energy produced with a classic wind turbine park of the same sizes.

Keywords: wind turbine, compact module, wind energy, propeller less, vertical turbine

Introduction

At present and in the near future, over 70% of the electric power production is obtained from fossil fuel burn-up, a process which is generating gaseous and solid pollutants, while the process of uranium nuclear fission reaction generate some amounts of long half-life radioactive wastes, which, in case of accidents, are likely to negatively affect large areas in the long run.

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Energy requirements have been increasing year by year, with few exceptions in times of crisis, leading to the exhaustion of traditional fuel sources. Therefore, currently, the development of new economically efficient energy sources is an utmost priority, besides the increase of the efficiency of the existing power plants and the reduction of the energy consumption.

Despite the efforts recently performed in the domain of using the new energy sources, the share of the fossil fuels in the production of energy couldn't be reduced and substituted with other energy sources, but, on the contrary, an increase of their share has been noticed.

The most dramatic consequence of air pollution is the global warming effect due to the negative impact of the greenhouse gases. Nuclear fuels currently have a relatively small share in the electric power production worldwide. The new type of nuclear power plants, advanced in terms of safety and technological processes, is expected to increase the share of nuclear fuels in the global energy production. And yet, in most developed countries the launching of new nuclear programs is being delayed for various reasons and interests.

The limited quantity of classical and nuclear fuels and the direct and indirect pollution which accompany the electric power production based on such fuels, demand, among other things, the search for new sources of primary energy and efficient procedures to transform it into electricity. That is why the scientific community has been deeply involved in the study of some old and new possibilities.

As many of us already know, since ancient times, wind energy has been used in the shape of windmills (first used in China) to produce power for various usage and developed on till the current wind-power turbines capable to generate a unit electric power up to 2.5 MW at 12 m/s wind speed [4].

Unfortunately, the process to convert the air stream (wind) kinetic energy into mechanical rotation energy used in the past and even nowadays, has not experienced essential improvements. The straight action developed by the movement of the mass of air along the surface of some profiled blades that rotate a shaft generating some mechanical rotation energy, electrical energy respectively, is even nowadays partially employed. Such a technology is allowing the use of maximum 20% of the wind kinetic energy generated by the blade rotation.

The need to increase the unit power of wind-power turbines has recently led to enlarging the blade sizes, with negative consequences both on the economical feasible operation of the wind potential in a certain area and on the environment. Despite such a progress, wind power, which is actually for free and all over the world, is now inefficiently used and represents a very small share in the electricity power production (less than 2%).

The wind power turbines based on the windmill design, currently in use, have the following disadvantages:

- have large, heavy rotating parts that are liable to self- damage at high air stream speeds;
- have large size blades and high anchoring towers which require the use of large air streams which at the lower part may be several times different from the air stream speed on top. Such an inconvenience is decreasing the efficiency of the air stream kinetic energy conversion

into a mechanical rotation energy i.e. electricity;

- use only the straight action of the air streams with a relative low efficiency and dependent on the blade size and profile (shape);
- operate only in a narrow range of wind speeds, usually 3.5–12 m/s, function of the blades sizes, due to the inertia and centrifugal forces generated;
- require large distances between adjacent wind towers, as much as 10 times the height of the supporting pillars;
- pose significant difficulties in fabrication, transport, installation, and maintenance due to the extra-sized components;
- show a negative eye impact on the landscape and represent some risks for the birds which use the low- high air streams for flying.

The new procedure and equipment associated to the production of the electricity based on wind power are innovative by comparison with the classical procedures applied so far, in that they convert the air stream kinetic power into electric power using the direct and indirect action of the air streams on a penetrable material blade turbine and the equipment is a small size modular type without outer rotating parts. We call this "Generation 2" of wind powered turbines [1, 2, 3].

With the new procedure, the investment costs related to wind power production are reduced almost 50% and the service life of SERB type turbines is increased by more than 30% because the wind speed range they can operate is larger than with the classical wind turbines. Moreover, the new wind powered turbines need not be installed at big height, neither do they need large distances among them, and they may be installed on spatial networks so that the wind power generating operational surface is economically increased.

The new procedure and technology for the electric power generation from wind power is falling-in the concept of sustainable, ecological and effective technology for the following reasons:

- Electricity production is achieved out of an inexhaustible source for as long as the solar system exists (the Earth crust uneven heating generates air streams whose kinetic energy, including low intensity ones, can be converted into electricity using new SERB wind-power turbines);
- With the new technology, the material consumption for building the wind-power turbines is relatively low, and their installation in different locations requires relatively few materials and energy consumption , also associated to a shorter construction time than the case of the current wind turbines;
- The sizes of SERB wind power turbines are about 5 to 10 times smaller than the current turbines with the same performances for the same installed power and the operation time of SREB wind turbines is increased because they can generate electric power even at low wind speeds (2 times lower speed). Moreover, at high wind speeds, SERB wind turbines need not be shut-off because there is no risk of self-damaging;
- SERB wind power turbines may be installed in urban centers on top of the existing buildings because they may be arranged in a network configuration of braced low pillars and there have no outer blades which may require

a certain installation height for the turbines on the building top;

- Erection of SERB wind power turbines on certain sites does not require high-scale construction-installation works and neither large, heavy, power consuming and polluting equipment is necessary (the new turbines are modular type and are sequentially installed by simple bolt assembling);
- The new SERB wind power turbines are actually making use of the entire energy available in a wind park by the direct and indirect use of the air streams, and the electric power produced is beyond 100 times greater than the electric power produced by a traditional wind turbine park.

Financially, it may be appreciated that the investment on installed MW produced by a wind park employing SERB wind power turbines is at least 50% smaller than with the current wind turbines, specially due to the increase of the unit power along with the reduction of wind turbine sizes.

Serb wind power turbines

SERB wind-power turbines remove the disadvantages of classical wind turbines and can be used in several constructive alternatives[1, 2, 3].

Serb wind turbines module

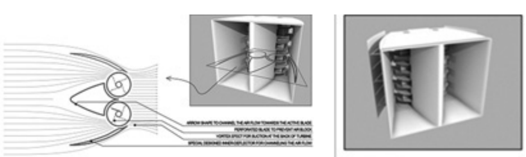

Fig. 2.1. Frontal view with two vertical rotors and uniquely designed deflectors

Modular turbines extract 5 to 10 times as much energy from the wind than classical turbines at any wind speed due to the following features:

- achieve maximal wind energy transfer to twin rotors' blades by optimizing the direct and indirect airflow action;
- focus and increase airflow speed with aerodynamic shape of lateral deflectors and central wing;
- induce rear horizontal mixing vortices between air streams flowing on module's interior and exterior areas;
- suck air flowing on module's exterior through lateral exterior suction channels;
- expand air flowing on module's interior in the rear outlet section through lateral interior dilation channels;
- optimize blades' geometry and degree of air penetration to increase air flow action;
- multi-level, lagged design, made of perforated thin steel sheets;
- smaller, faster, robust.

SERB wind turbine tower

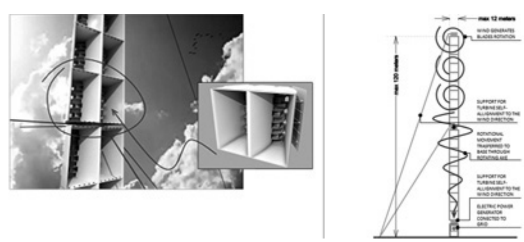

Fig. 2.2. SERB wind turbine tower

Modular Wind Turbine Tower:

- harvests wind energy from a large rectangular area;
- operates efficiently and safely at low as well as high wind speeds;
- adjusts rotor's diameter (from small at the bottom to large at the top) to

match the variation of wind speed along turbine's height for maximal operational efficiency;
- allows for easy transportation, installation, and decreased weight due to hallow, frame-braced, easily assembled modules;
- allows for easy maintenance due to simplicity of the mechanism transferring rotational movement to the electric generator located inside the easily accessible supporting pillar at the bottom of the tower.

SERB wind on-shore wind turbine micro-farm

A modular turbine wind farm can produce 100 times more nominal electric energy than a classical turbine wind farm using an equivalent area:
- turbine towers are compact and can be placed close together in micro-farms optimizing land;
- a micro-farm includes at least three turbine towers to as many as permitted by relief and airflow characteristics;
- a micro-farm is anchored to the ground by cables to bearings that allow self-alignment of turbine towers to the dominant wind direction;
- micro-farms can be placed at short distances from each other determined solely by the anchoring system and wind flow characteristics;
- micro-farms can be assembled easily on-shore as well as on floating platforms off-shore;
- modular wind turbines are inherently safer and need not be placed away from people, birds and buildings.

In Fig. 2.3.1–2.3.3 is presented a modular turbine wind farm.

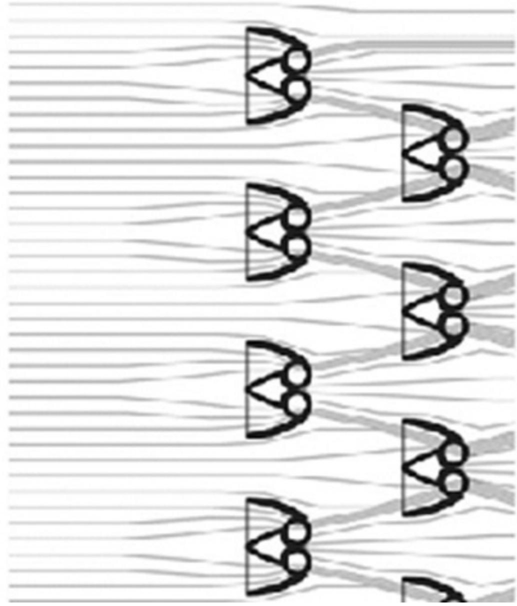

Fig. 2.3.1. Grid layout of turbine towers in a micro-farm to optimize electric power output and land usage

Fig. 2.3.2. Wind turbine farm is firmly anchored to the ground at multiple levels

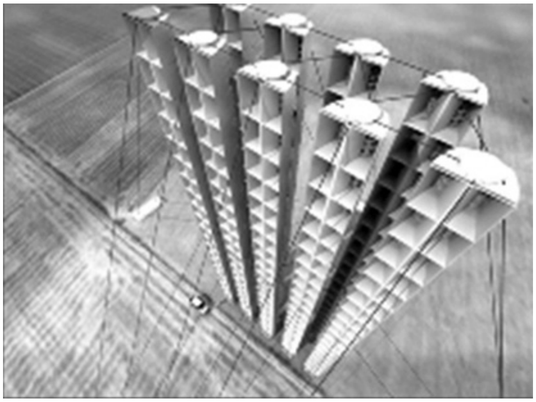

Fig. 2.3.3. Towers are interconected with cables to form a rigid structure

SERB wind off shore wind turbine micro-farm

Offshore wind turbine micro farm installed on floating, self-orienting platform; platform is mobile when rotating and rigid when transiting/transferring:

- off shore wind turbine towers are mounted on circular, floating, self-rotating platforms that can move in a circular motion;
- off-shore wind turbines are modular, vertical axis turbines, typically made of 6mx6mx6m sized modules; the turbine collects the direct and as well as indirect (through suction) wind energy from a large rectangular surface;
- platforms rotate as a block along the prevailing wind direction along a circle shape through a combination of special geometrical features and use of air resistance forces generated by tower wind turbines; a rear wing can provide additional guidance;
- platform stability is ensured by an upside down pyramid shape of the bottom side and by three point anchoring at a depth of 6 m from water level;
- conversion and power transfer equipment are installed in the central and rear tower as well as in the inferior frontal side; a power battery can also be placed in any of these areas o adjust the gap between production and consumption of energy.

In Fig. 2.4. is presented an offshore wind turbine micro-farm.

Fig. 2.4. SERB off shore wind turbine micro-farm

SERB wind urban wind turbine – terrace

Fig. 2.5.1. Urban wind turbine for buildings

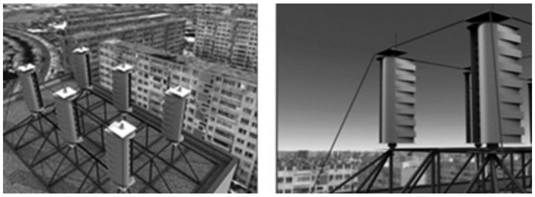

Fig. 2.5.2. Wind turbine micro farm. Installed on building roof

- utilize ascending air currents streaming on the facades as well as horizontal air currents blowing on the roofs of buildings ;
- tower-shaped and enclosed in a self-orienting carcass that facilitates collection, concentration and redirection of air currents;
- to maximize wind energy capture, cornice and terrace wind turbines can be combined in a single structure; cornice wind turbines are placed on a building's parapet while terrace wind turbines are installed on its roof;
- turbines can be grouped in micro-farms with a rigid position by ballasting and use of rigid cables to connect towers together and link the entire structure to a strong base; the turbine structure does not affect the protection layers of a building ;

SERB wind urban wind turbine – cornice

- cornice turbines can fully capture energy of ascending wind current generated by super pressure on the facades as well as the energy of the air currents on the top sides of a building.
- has a special horizontal structure and deflectors that direct air currents and help generate vortices with suction effects;
- simple installation procedure on a building's cornice without affecting existing layers a string of modules can be connected to electric generators placed at either one or both ends.

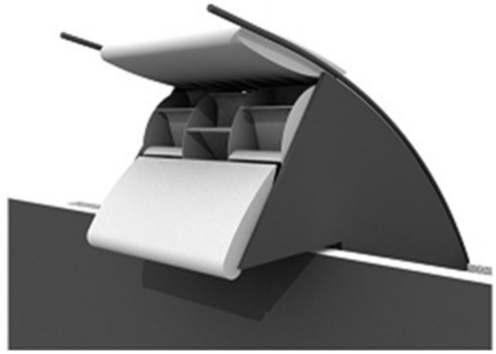

Fig. 2.6.1. Cornice module with deflectors

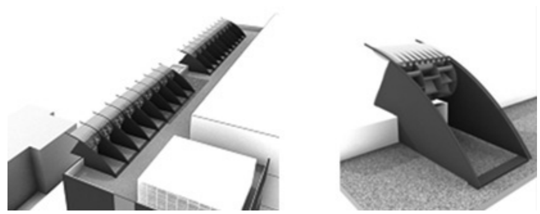

Fig. 2.6.2. String of cornice modules I Installed on building roof

SERB wind street wind turbine

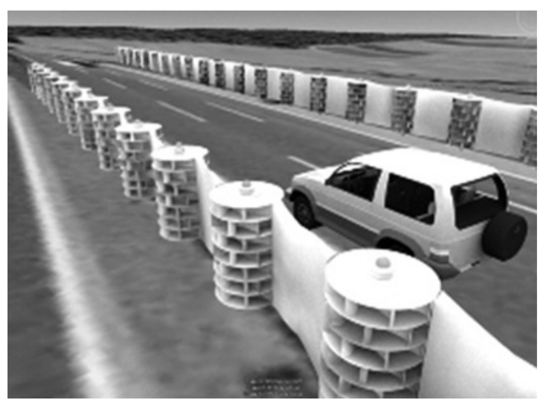

Fig. 2.7.1. Street wind turbines placed on the central and side strip. Areas of a highway

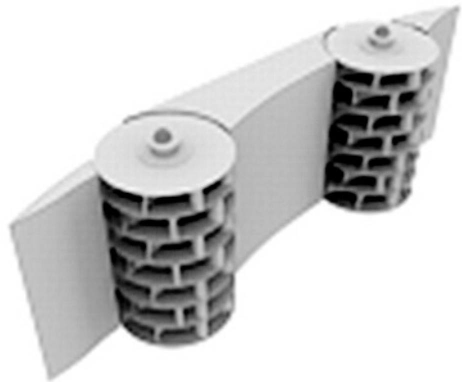

Fig. 2.7.2. Street wind turbines placed on the central and side strip. Areas of a highway

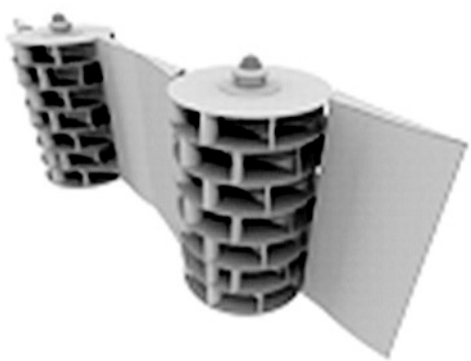

Fig. 2.7.3. Street turbine for center strip

- vehicles in motion generate air currents (local wind) that travel a distance depending on vehicle size, shape and speed;
- street wind turbine micro-farms can be install on the central and side (in some case) strips of highways and other major streets;
- street wind turbine micro-farms can be manufactured as sound-absorbing panels to significant reduce noise generated by moving vehicles ;
- street wind turbine micro-farms increase safety by providing physical separation of traffic running in opposite directions and serve to protect from the headlights of cars running in reverse direction;
- street wind turbine micro-farms can capture up to 45% of the energy of air currents generated through vehicles' motion.

Conclusions

SERB technology to transform the wind energy into electricity and the applications presented herein, are innovative and protected and patented by OSIM for recognizing the priority in the domain.

The new types of wind turbines can be fabricated at any scale, from small sized wind turbines for the supply of an isolated consumer to turbines for industrial applications. SERB wind turbines can actually eliminate all the disadvantages related to the classical wind turbines and may also be installed in crowded urban areas or on buildings because they have no moving parts outside, are low weight and small sized.

The applications of the new technologies show the following advantages:

- SERB wind turbines can economically use up to 70–80% of the wind potential in a certain area;
- The construction of a SERB wind turbine park requires low investment and operation costs;
- SERB wind turbines are capable to operate at low air stream speeds and need not be stopped at high air stream speeds;
- SERB wind turbines show no risk of accident generated by the likely blade braking-off at high air stream speeds or bird hitting;
- The use of modules to reduce the air stream resistance at vehicles may

reduce the fuel consumption by about 20–40%;

- The flying vehicles that employ the new technology are more efficient, safer and less fuel consuming than the classical ones;
- The system for the electric power accumulation in the form of potential mechanical energy shows several advantages if compared with the classical systems by that SERB system is using the same supporting system for both the wind turbines and the energy accumulators.

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Wind Waves Power Turbines

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Waves are a form of energy storage transferred by the wind to oceans and seas.
According to present estimates the waves' energy can be exploited on a viable economical basis, when its linear potential surpasses 15~20 kW/m.
Using only 10% of this energy would be sufficient to meet current global energy needs.
With all the improvements made to present day the systems for converting wave energy into electricity still have some disadvantages: small unit power; converting wave energy into electricity requires the use of an intermediate circuit that reduces the efficiency of transformation; short life span; water pollution with liquid (oil) used as working fluid; high investment and maintenance costs.
In the project on the basis of inventions are developed new types of wave energy conversion systems that largely eliminate the disadvantages of current systems. This system can be used for both wind waves and for tidal waves. Wind waves turbine consists of a large rectangular enclosure partially submerged in the water deeper than the waves' amplitude.
The vertical position of the enclosure wave turbine and its buoyancy are ensured by ballast and building walls and large areas of lightweight composite materials, polystyrene and advanced textile of high strength fibers to provide a buoyant force. The initial investment for new types of wave turbines is reduced several times up against the current wave turbines. The cost of produced energy is comparable to the cost price of energy produced from traditional sources under 0.04 €/KWh.

Keywords: wind and wave energy, wave power turbines

General overview

The continous motion of wind transfers energy from an air mass in rectilinear motion to a water mass causing an oscillatory motion known as wave (see Fig. 1.1. and 1.2.). Waves behave as energy accumulators as once formed they propagate over large distances due to water's incompressibility and nondisspatory quality.

According to current estimates, wave energy can be exploited on a viable economical basis when its linear potential (the standard

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unit for the linear potential of waves is the annual average wave power on a 1 m width of the wave's crest parallel to the shoreline) surpasses 15~20 kW. As shown in Table 1, the achieved distance over which a wave develops, its duration, height and period depend strongly on wind speed, which in turn is generated by the uneven distribution of solar heat on the surface of the earth. [1]

Fig. 1.1. Ocean wind waves

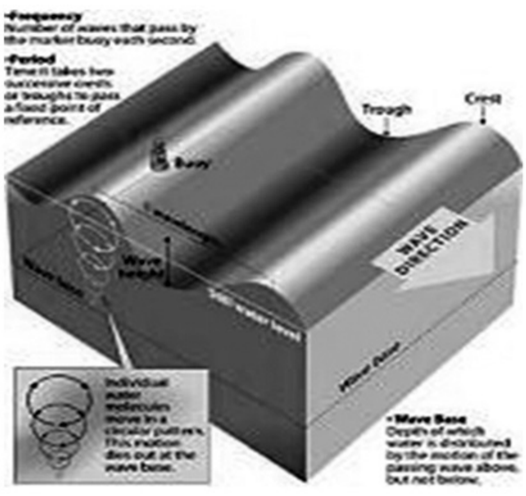

Fig. 1.2. Wave caracteristics

Since a wave's energy is directly proportional to the square of its amplitude, effective systems of wave energy conversion into electricity will weigh heavily the global electricity production.

Table 1. The realationship between wind speed and wave parameters

Wind speed	Achieving distance	Time	Height	Length	Period
(Km/h)	(km)	(h)	(m)	(m)	(sec)
20	24	2.75	0.33	10.6	3.2
40	176	11.50	1.80	39.7	6.2
60	660	27.50	5.10	89.2	9.1
80	1682	50.00	10.30	158.6	12.4

The waves's energy is directly proportional to the square of its amplitude and if there are effective systems of wave energy conversion into electricity, this could weigh heavily in the actual production of electricity.

Energy potential of ocean waves

Waves are a form of energy storage transferred by the wind to oceans and seas (see Fig. 2.1.)[2, 5]. The largest storage of wave energy is concentrated on the west coasts at latitudes between 40° and 60° in both the northern and southern hemispheres. Energy contained in wave crests varies between 30 and 70 kW/m, reaching levels of about 70 kW/m in the West Atlantic ocean of Ireland and in the extreme south of Latin America, and 100 kW/m in New Zealand as indicated in Fig. 2.2. [3]. The long-term annual wave power level increases from about 25 kW/m off the southernmost part of Europe's Atantic coastline (Canary Islands) up to 75 kW/m off Ireland and Scotland (Fig. 2.3.). In the North Sea, the resource changes significantly, varying from 21 kW/m in the most exposed (northern) area to about the half of that value in the more sheltered (southern) area. In the Mediterranean basin, the annual power level off the coasts of the European countries varies between 4 and 11 kW/m, the highest values occurring for the area of the south-western Aegean Sea [3]. The capture and conversion of just 10% of this wave energy is sufficient to meet current global energy needs. Annual economically exploitable sea and ocean wave energy new resources are evaluated at 2000 TWh/year.

The total power of economically exploitable waves around Europe is of over 320 GW.

Wind resources over open sea (more than 10 km offshore) for five standard heights										
	10 m		25 m		50 m		100 m		200 m	
	ms^{-1}	Wm^{-2}	ms^{-1}	Wm^{-2}	ms^{-1}	Wm^{-2}	ms^{-1}	Wm^{-2}	ms^{-1}	Wm^{-2}
	> 8.0	> 600	> 8.5	> 700	> 9.0	> 800	> 10.0	> 1100	> 11.0	> 1500
	7.0-8.0	350-600	7.5-8.5	450-700	8.0-9.0	600-800	8.5-10.0	650-1100	9.5-11.0	900-1500
	6.0-7.0	250-300	6.5-7.5	300-450	7.0-8.0	400-600	7.5-8.5	450-650	8.0-9.5	600-900
	4.5-6.0	100-250	5.0-6.5	150-300	5.5-7.0	200-400	6.0-7.5	250-450	6.5-8.0	300-600
	< 4.5	< 100	< 5.0	< 150	< 5.5	< 200	< 6.0	< 250	< 6.5	< 300

Fig. 2.1. Wind resources over open sea in Europe

There is an engineering problem and consists in designing the most efficient systems that capture these enormous amounts of energy.

The Electric Power Research Institute in the U.S. claims that the energy produced by 50% efficiency wave power plants exploiting just as little as 20% of wave energy along the U.S. coast would exceed all the energy produced by all the hydropower plants in the U.S.

Romanian specialists forecast that the gross energy potential of waves on the 200 km cost of the Romanian Black Sea amounts to approximately 8 TWh/year, with half of this power potential being technically usable, and consequent savings in conventional fuel consumption of around 2 million tons per year.

The design of efficient systems to capture this enormous amount of wave energy is still an engineering challenge!

Fig. 2.2. Distribution of wave power in kW/m on a crest length of 1 m

Existing conversion systems for ocean waves

Unfortunately, current systems for the conversion of wave energy into electricity are not efficient, and are difficult to implement and exploit [3, 4]. The existing systems can be classified into two categories, as follows:

- Systems based on the oscillation of a water column.

In a bottomless chamber, partially submerged in water and the rest with filled with air, an air cushion communicates with air above the water through a top channel where a wind turbine is mounted. The oscillations of interior water volume due to waves on the outside of the half submerged enclosure cause volume variation in the air cushion in the chamber generating an air current that rotates the blades of the wind turbine positioned at the top of the chamber.

- Systems with floating elements

The floating elements of this wave energy conversion system rotate alternately or oscillate vertically depending on wave amplitude and system type. Typically, the rotating or oscillating movement pushes a pressurized liquid through a pump system that sets into motion a turbine connected to an electric generator. Alternatively, the oscillatory movement may be transformed into a continuous rotational movement through a system of gears and sprockets that alternately pick the oscillating movement from opposite directions.

Limitations of exiting conversion wave power systems

Despite recent improvements, the existing systems for converting wave energy into electricity still exhibit a number of some significant disadvantages:

- Small unit power,
- Conversion of wave energy into electricity requires usage of intermediate circuit that reduces the efficiency of transformation,
- Short life span,
- High maintenance costs,
- Water pollution (seas and oceans) from liquids (such as oil) used as working fluid,
- High specific investment costs per installed KW (over 2500 €/KW) and high price of generated electric energy (over 0.08 €/KWh).

New wind waves turbine

In this project, we develop new types of wave energy conversion systems that largely eliminate the disadvantages of existing systems. The inventions are protected by the State and Trademarks Office of Romania.

The new wave turbine as shown in Fig. 4.1–4.5 consists of a large rectangular enclosure partially submerged in water at depth larger than a wave's amplitude. The enclosure is divided into several compartments by reinforcing walls. Each compartment is separated into and inlet and outlet chambers, respectively.

An inlet and outlet channels span the entire length each chamber's bottom, respectively. A horizontal cylindrical rotor with an axis shaft on the joint wall is mounted at the top of the inlet channel and outlet channels. The bottom inlet channel has several intake valves that block water discharge. The bottom outlet channel has several exhaust valves that block water inflow. The rectangular enclosure may be opened at the top in which case its height must be larger than the amplitude of the waves. When the enclosure is closed at the top, communication with the exterior can be achieved through several vertical tubes designed to prevent water from flowing into enclosure from the top. The length and the width of the enclosure are determined and must be adjusted to the desired unitary power of the wave turbine. The width of both the inlet and outlet channels must be equal to half the diameter of the turbine. The common wall on the lower and upper portions of the rotor has a curved surface along the direction of the water.

The two chambers are separated by a vertical wall that passes through the turbine's rotor shaft axis, and is connected to the cylindrical wall in the narrow area at the top of the turbine's rotor, to the exhaust outlet chamber, to the cylindrical wall in the narrow area at the bottom of the turbine's rotor, and to the inlet channel that directs water to the rotor blades.

The cylindrical turbine rotor has a shaft with attached discs with concave blades that are rotated by the neighboring sections' blades.

The length of the transversal compartment should be smaller than half the wave length to allow for the independent action of each compartment on the cylindrical turbine blades, regardless of the lifting or lowering phase of the waves.

The horizontal turbine rotor shaft is provided with several Teflon bearings with graphite or bronze insertions at both ends.

A gear with conical teeth is fixed at one or both ends of the turbine shaft. Each gear engages with another to switch 90° the direction of the rotational movement of the shaft as well as to amplify its speed.

The gear wheel assembly is locked in a tight oiled enclosure to ensure the efficient lubrication and cooling of the gear. The rotational movement and torque are transmitted to an electric generator through several shafts and couplings.

The turbines may be located parallel or perpendicular on the direction of wave propagation in the water volume. The wave turbines are anchored through bottom by elastic elements attached to concrete blocks placed on the seabed.

Ballast, building walls and large areas of lightweight composite materials, polystyrene and advanced textile (fabric) of high strength fibers ensure the vertical position of the enclosure and the buoyancy of the wave turbine. Large light bodies made of the same materials may be connected may be connected to the exterior of the enclosure to provide an additional buoyant force.

The operating principle of the new wave turbine as shown in Fig. 4.6–4.10 is the following:

- when the wave rises, the flaps (valves) close the outlet channel and allow the water through the inlet channel to activate the rotor blades, located at the inlet channel;
- the water accumulates in the upper inlet chamber of the turbine to a level lower than the wave's height;
- a small amount of water enters the upper exhaust chamber activating the blades located at the top of the rotor in the same rotational direction;
- during the first lowering phase of the wave, the flaps (valves) in the inlet channel are closed and the water from the upper inlet chamber passes into the upper outlet chamber by pushing on the blades located at the top of the rotor;
- during the subsequent lowering phases of the wave, the flaps (valves) in the outlet channel open and the water accumulated in the outlet chamber and the inlet chamber is evacuated pushing on the rotor blades located at the outlet channel;
- the process repeats when the wave is rising without interrupting or stopping the rotor's rotational movement;

We recommend splitting the enclosure into multiple sections so that the turbine's operation is not affected by the raising or lowering phase of the wave regardless of the turbine's position with respect to the direction of the wave's propagation as well as to obtain a constant speed of ration of the turbine's rotor blades in all phases of rise and fall of the waves.

The initial investment costs for the new type of wave turbines is several times smaller than for existing wave turbines. The unit price of energy generated by the new system is comparable to that of energy produced from traditional sources, specifically under 0.04 €/KWh.

The new advanced textiles and composites will be used in the construction of the wave turbine to achieve the following goals:

- to protect the enclosures, chambers, channels, as well as the inlet and outlet flaps of the turbine in high level salt waters;
- to build the buoyancy system and ensure its viability against corrosion;
- as the components of the new wave turbine will incur complex stress actions (due to compression, tension,

shear, and bending actions), the materials must be reinforced through a sandwich-type structure;

Importantly, the composite materials and the structural elements embedded in the sandwich structure will ensure the necessary resistance of the elements. The components must be large in volume to ensure buoyancy. This is accomplished by the use of lightweight materials such as polystyrene, and the application of the new advanced textiles on all sides.

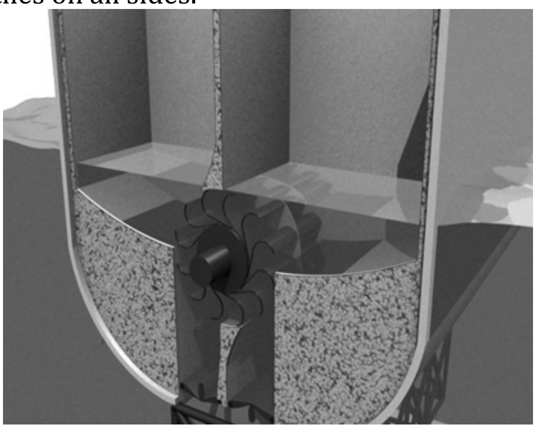

Fig. 4.1. Wind waves turbine – Cross section

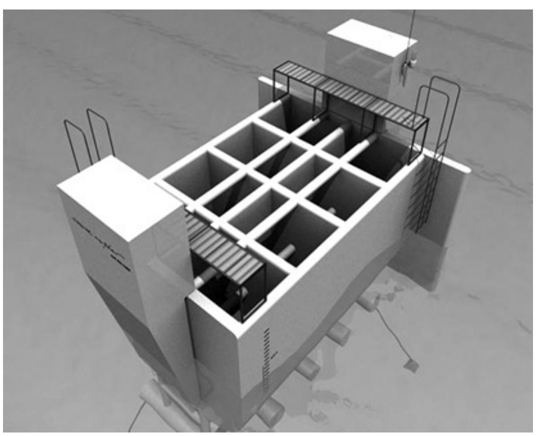

Fig. 4.2. Wind waves turbine. Parallel to the direction of wave propagation – Top view

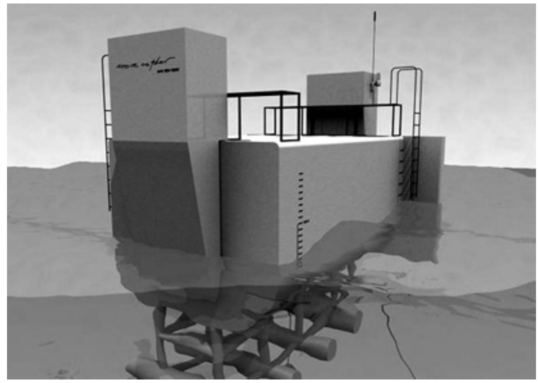

Fig. 4.3. Wind waves turbine. Parallel to the direction of wave propagation – Lateral view

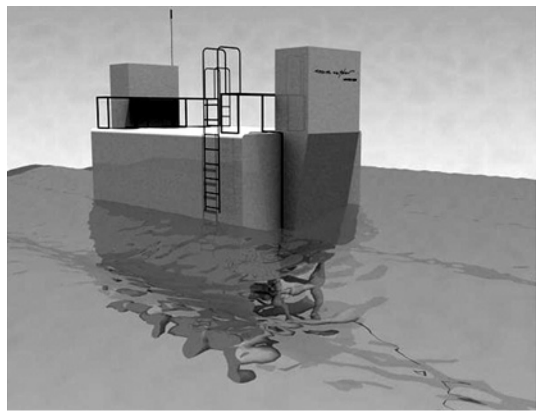

Fig. 4.4. Wind waves turbine. Perpendicular to the direction of wave propagation – Lateral view

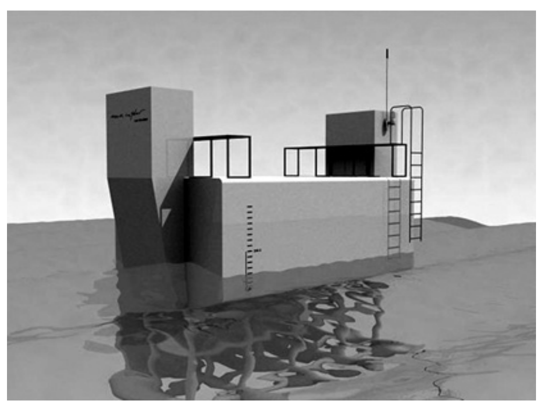

Fig. 4.5. Wind waves turbine. Perpendicular to the direction of wave propagation – Front view

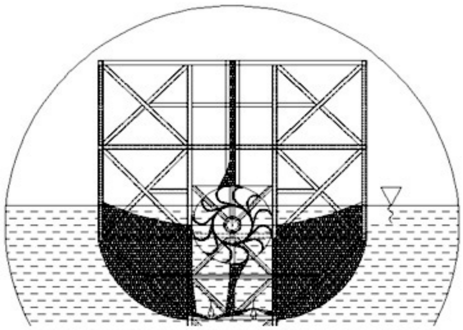

Fig. 4.6. Phase 0: Wave Initiation

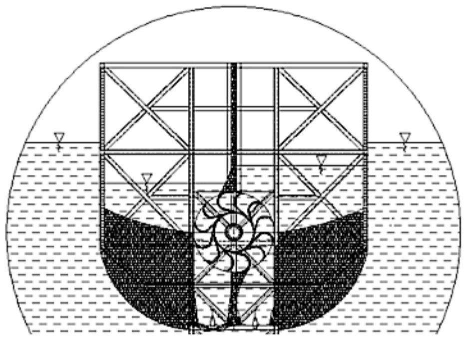

Fig. 4.7. Phase 1: Wave Low Rise

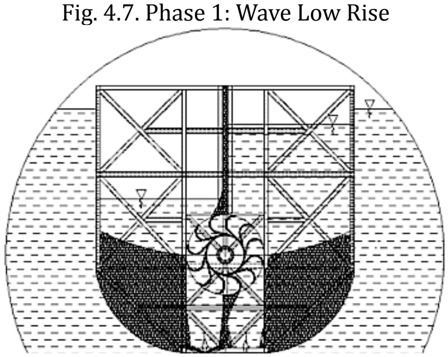

Fig. 4.8. Phase 2: Wave High Rise

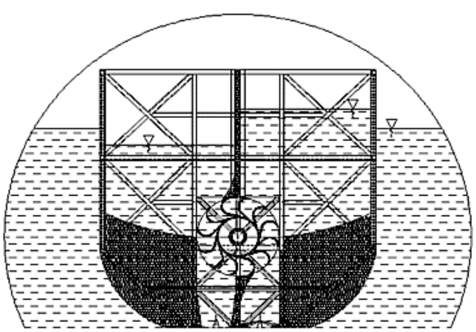

Fig. 4.9. Phase 3: Wave Low Lowering

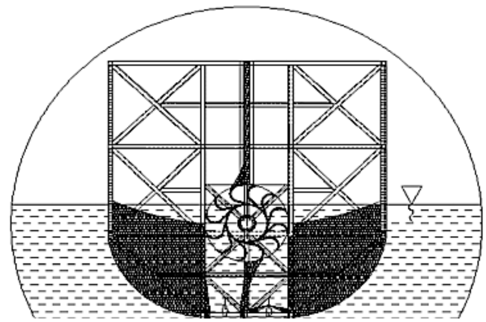

Fig. 4.10. Phase 4: Wave High Lowering

Tidal wave turbine

The tidal wave turbine is structurally and functionally similar to the new wind turbine, but it is much larger in dimensions and has a fixed position.

In the tidal wave turbine, a much larger volume of water enters and exits each chamber, but has a smaller dynamic flow, emptying the chamber within 6 hours and 12 min.

Tidal waves turbines must be located near shores where tide amplitude is maximal. Tidal wave turbines may also collect wind wave energy that overlaps the tidal waves as both act the rotor blades in the same direction so that the effects of the two waves' effects overlap and reinforce one another.

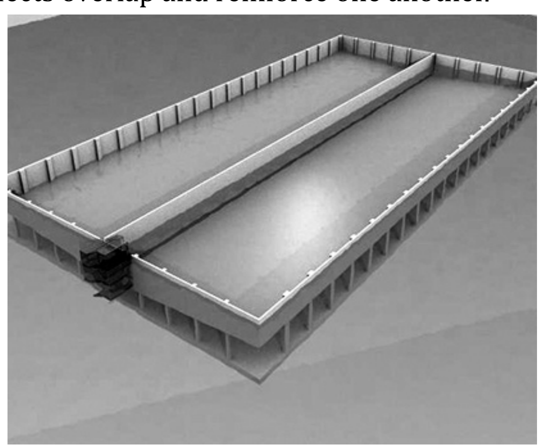

Fig. 5.1. Tidal wave turbine – Tidal star up

Tidal wave turbines may be built out of concrete, steel or composite materials, and using the new type of highly resistant, advanced textiles. In Fig. 5.1–5.4 are presented oparation phases for Tidal wave turbine.

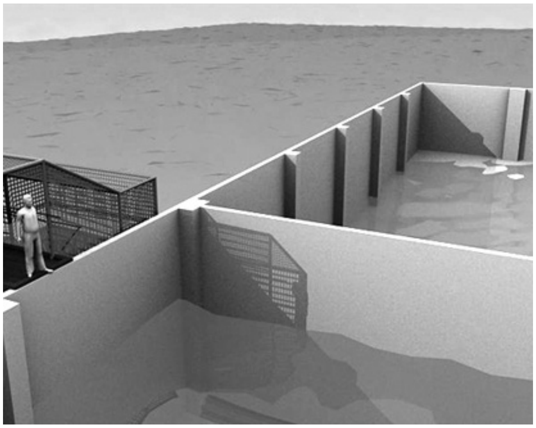

Fig. 5.2. Tidal wave turbine – Tidal lifting – Detail

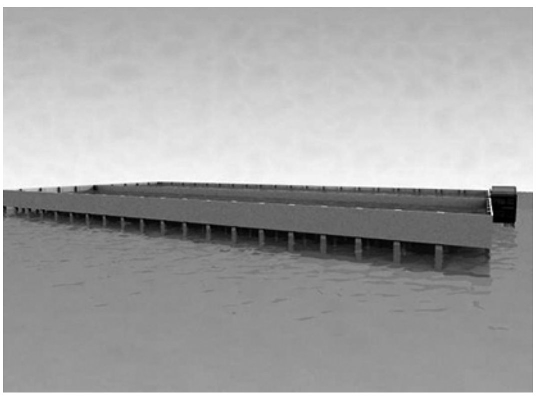

Fig. 5.3. Tidal wave turbine – Tidal lifting phase

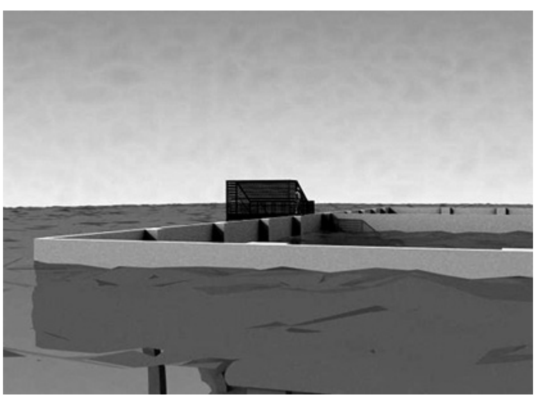

Fig. 5.4. Tidal wave turbine – Tidal maximum lifting phase

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The Traditional Bioclimatic Architecture in the Romanian Geographic and Climatic Context

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The issue of the energy resources is the subject of intense concerns, in various branches of activity for the contemporary society, in order to achieve their goals through the principles of the sustainable development concept. The building sector has always been placed in the context of the energy resources speech, due to the important natural and financial resources requirements involved.
Bioclimatic architecture represents the building response in a harmonious relationship with the climatic conditions of a site, but not against them. The paper wants to illustrate the evolution of the architectural form and building's location types, in relation to the geographic and climatic conditions, characteristics for the Romanian territory. By means of strategically classification of the main characteristics of the place we will illustrate a mapping of different architectural typologies and the way they have responded to the climatic conditions. For this fulfil, we will take into account the solar energy conditions, wind movement and other site specific factors which influence the shape of buildings, from the climatic point of view.
The exposed theme is part of a doctoral thesis which aims to define an analysis methodology and design approach, respecting the principles of bioclimatic architecture on the Romanian territory.

Keywords: bioclimatic architecture, vernacular architecture, climatic integration, energy balance

Introduction

Architecture has always been one of the essential means by which the man, through his activities, was able to adapt to the environment in which he lives. The evolution of the architectural phenomenon is a continuous interpretation of the act of becoming of a building design. In this paper we will refer to the residential sector, and particularly to the disposition and conformation of the house within its dwelling. We will follow the way the man adapted the architectural spaces to the climatic conditions and geographic locations of the surroundings in which he lives, in deep relation with his purely agricultural or animal husbandry activities.

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Given that this study seeks to reflect the conditions of architectural climatic adaptation, according to the historical period before the nineteenth century, the covered settlement types are those characteristic of rural areas, because only here their original features are most clearly distinguished.

After a preliminary indication of the main types of settlements and existing housing in Romania, climate issues which affect directly the architecture will be essentially considered, highlighting specific features of the Romanian traditional buildings in relation to their location.

A bioclimatic approach to architectural design implies the way that configuration of the building responds to the geo-climatic conditions of a specific site, from the spatial, functional, dimensional points of view. Invoicing traditional architecture, often called vernacular architecture, is intuitively adapted to a specific climate in relation to human activity. From here one can take the conclusion that most often the traditional architecture has a profound bioclimatic approach.

Traditional Housing in Romania

Initiating with the principle that human activity is a generating factor of the architecture, for instance we admit that building is the most favourable outcome of adapting to the user's needs. Looking globally from the geographical point of view, the specific human activity of a certain place is also the result of climatic conditions and topography compliance. From this ideas context, one can extract the conclusion that traditional architecture is the result of a system, in close relationship to the particularities of place and its essential characteristics. [1] This kind of approach is respecting the principles of bioclimatic architecture, developed organically around human activities.

The disposition and form of traditional settlements in relation with the territory

Given the previously reported, reiterating it Grigore Ionescu, there are two issues that underlie their configuration and disposition of settlements in the territory: their form and activities of the inhabitants [2]. The settlements are an important economic factor and geographical positioning, in defining their character [3]. On Romania's surface there are three types of villages: spread, scattered, grouped. The classification is following the principle of the territory layout of households. These, in terms of relief, in conjunction with specific activities such as settlement and distribution of property in the territory, have complied with the long periods of time. Thus, the mountain villages are characterized by isolated arrangement, because attempts to adapt to topographical difficulties of the land. Here, pastoral activities are the main activity that led to the adoption of architectural types with permanent or seasonal use. In hilly terrain, the layout of settlements aimed at areas with large valleys protected from the direct action of climatic agents. In addition to shepherding, they were occupied with farming and fruit growing. The main lowland agricultural character of the settlements in plain is mostly located in the meadows or valley bottoms.

Understanding these factors in terms of rural development is a considerable element that allows the formation of an organic system of dwelling adaptation to specific climate issues.

Fig. 1. The Romanian historical provinces [4]

The spread village

It is found in mountainous regions, where households are isolated and at great distances apart. The house, polarizing owned land, is positioned at random, where are found suitable living conditions: the sunny areas, less rough, and as protected from extreme climatic agents. Here, the relationship between human interventions and nature, promotes the natural spontaneous vegetation as dominant presence. This type of settlement is common in the Apuseni Mountains, between the Crisului Repede Valley and Muresului Valley, north-east of Transylvania, the upper basin of Bicaz, Suceava Area, Trotus Upper Basin, northern border of the Carpathians, on the banks of the Olt Valley and the south-east of Banat [5].

The scattered village

The hill and valley regions are hosting the most common type of settlement in Romania. The emergence and development of scattered localities did not follow clear rules, for which they are arranged irregularly in the area. The settlement of households finds its origin in the formation of local groups such as hamlets, irregularly arranged between them, with the houses located at the limit of the road. Transport routes are irregular, following the terrain topography. This time, in the relation between built space and nature the first one increases its importance. Nature gets only the character of the ambiance and picturesque surroundings.

The grouped village

The third type of settlement is largely characteristic of lowland areas, but often is present in the hilly and mountainous regions, as a result of conditioning to adapt to the available land [6]. Particular areas of this model are Baragan or Oltenia [7]. Although they developed organically, in this case households are regularly distributed in territory and compact within the locality. Housing is arranged by the road. In this category, in Romania there are two categories, depending on cultural background: a local one which respects the above description and the other with Germanic origin. The second one is not an indigenous style in particular but a typology implemented by policy decision. But the result is a definition in relatively similar climatic conditions and a consequence of a different type of mentality, characteristic of a different culture. The model is, however, adopted over 700–800 years old and very widespread in Transylvania.

Types of configuration of vernacular housing in Romania

We tried to avoid the use of clear examples of building in the respect with the theme we are opening in discussion, from the desire to present rather the essence of representative cases for different geographical areas of the country, but also because of the impossibility to exhaust the subject in this paper.

Transylvania

Transylvanian typical household is compact, well sealed on all sides and developed around an inner courtyard. It represents the result of a type of development characterized by the absence of site and immediate neighbourhood, resulting in the need to control the space around the perimeter. This typology is normally taken in the spread or scattered villages in the area.

Housing is arranged so as to take advantage of the main benefits of the energy characteristics of the place. The roofs of two or four plain have extremely high slopes, often reaching values three times higher than the actual height of the dwelling space [8]. The roofing coverings are made with first-hand available materials: straw, wood shingle or ceramic tile [9]. Many times the house has a stone foundation or stone cellar.

Brick and stone are constantly used beginning with the twentieth century for walls and basements, being rarely used on houses in rural areas before. These materials had been used since the nineteenth century in Banat and Transylvania in particular Barsa County, Marginimea of Sibiu, Tarnavelor County etc., all being areas strongly influenced by urban architecture [10].

Banat

The historical Banat region was strongly influenced by the presence of invoice Habsburg culture, appearance embodied also in the architectural form of housing. Climate adaptation is following the same type of bioclimatic architectural principles as in the rest of Transylvania, but materialised in different materials. The roofs is achieved in two plains, steep slope, the covering is ceramic tile. The different buildings are constructed of stone and burnt brick masonry or stone foundations and superstructures of wood planks. The houses are fitted with a porch.

Maramures

In this region the people have applied similar rules to Transylvania area but using organic vegetal materials. Wood is predominantly as a construction material. Extremely high roof has four slopes, is covered with wood shingle or straw. And in this case the porch is an important presence feature.

Moldova

Due to geographical variation of Moldova, one can meet here several types of related housing, but applied differently. Here was present the ground floor developed house, with porch, like housing in Transylvania. The porch is conducted on one, two or three sides of the building. The shed, space for livestock and storage, appears on the northern side. Coverage is made of wood shingle, reed or straw rye grain [11]. Depending on the amount of rainfall, roof plane changes its inclination. There are wide eaves to protect the foundations and walls of direct precipitation.

Houses often have foundations of stone, apparently left wooden body or daubed with earth, water coverage increased in four planes, with wood shingle roof.

The presence of vineyard areas led to the adoption of the cellar at ground level, having the role of storage. This presence raised the one floor house typology to a higher floor of the building, giving birth to the gazebo.

Dobrogea

One of the first models of construction in our country is the earth hut. It was originally spread across the whole territory of the country, built from economic and defence reasons. Yet because of the geographical relief configuration has been mainly built in Dobrogea.

Towards the Dobrogea Plateau and the coast, houses are made of oak and present hipped roof line, covered with tiles, certifying the ancient Greek influences of the area [12].

The delta area homes have porches, thatched roofs with a slope greater than Dobrogea Plateau [13] for a faster flow of rain water. The roofs often show two slopes, rarely four. One can find here adobe houses, covered with reeds in the delta areas. Wood, a rare material in these places, is used to achieve the porches.

Even here, the shed comes as an extension area built on the northern side of the house, a loan of traditional architecture in Moldova.

The strong presence of the windmills in this geographical area of Romania is certifying awareness of the benefits of wind energy.

Walachia (Muntenia)

Walachia houses were made of wood, on stone foundation, a specific system of hills and mountain areas.

Fruit growing influenced in particular the typology of houses in this geographical area. Here the homes were equipped with a storage cellar used as depository elevated above the rest of housing construction. They are often fitted with porch and gazebo, a signal of higher material situations. Infrastructure was built of stone or brick masonry [14].

Roofing average slopes are covered with wood shingles or shakes.

In this region, there is evidence of the house shade on the rear side of the building, as a storage space for animals [15].

Oltenia

Oltenia is the most diverse area from the country, in terms of architecture [16]. Extremely varied landscape has led to the adoption of various types of housing configuration [17].

An example is developed on the ground floor houses with stone foundations, wood type superstructure, used in the more forest mountain areas.

In areas characterized by the cultivation of fruit trees was adopted the house model with stoned cellar basement and wooden superstructure.

Another option adopted was the house with basement, built of wood, earth and brick and covered with ceramic tiles.

The appearance of the turret marks the access to the basement, giving the house a particular superior aspect over the other types encountered.

Even in this geographical area the presence of earth huts indicates economic and defense reasons. They were covered in two slopes with a medium inclination due of the lack of high rainfall and the use of straw parcel [18].

Climatic characteristics compared with traditional Romanian architecture

Traditional architecture is an outstanding example of the applying of the bioclimatic architecture principles. In the following we pursue according to the main climatic factors, how this type of architecture has given the easiest answers for the presented population and technological possibilities of the ages.

Solar radiation

Solar radiation, both thermally and the characteristic of natural luminescence, involves important effects on the orientation of areas such as household itself and individual level of the dwelling. Apparent motion control on the geometry of the sun in the sky was the creation in its original form, of the typology of housing feature Romanian vernacular architecture: the porch house.

Direct solar radiation and fructifying energy by taking advantage of thermal storage in winter time has a limited effect due to the adoption of conservation strategy of the interior heat [19, 20]. It is therefore mainly exploited the effect of thermal inertia of building material and less accumulation of direct solar energy. The same strategy works during the hot weather. Over the summer, the presence on the southern side porch of the house, protected from heat accumulation emission, constitutes an obstacle to access sunlight.

Indoor lighting is more important during the cold season, when human activities are shrinking in the dwelling. In this sense, the small size of the windows has more functionally character dependent on the technological possibilities of the time.

Temperature

Considered one of the main elements of climate bill, the temperature affects directly several essential components of a building. Form construction is simple; it fits in a compact volume as to reduce heat transfer between the exterior and interior. A particular example is the case of earth hut construction in which this principle is exploited to the maximum.

The size and material for house building envelope contributes to the conservation of traditional Romanian home interior temperature at a constant value, thus allowing the performance of indoor thermal comfort conditions, regardless of season. Living quarters are small sized, height level is particularly low for economic reasons, but having high energy and quality is important compared with the user. Also the interiors are minimal in nature whereas functionally predominant activity taking place outside the home. An exception is the cold season, when occupations were taking place mainly in the interior. Hence results the increasing importance of thermal insulation in winter.

Houses built of stone, brick or earth capitalizes on the thermal inertia of building material, while the wood values more its thermal insulation qualities.

The small size of the windows helps reducing heating lost to the outside in winter period.

Relative humidity

This parameter, especially important in cosy atmosphere does not influence directly or in a particular, volumetric construction. However, widespread use of natural materials, the most convenient, vapour permeable, allows the natural adjustment of moisture. Hydrothermal control is also ensured by the presence of significant vegetation in rural areas, contributing significantly to the equilibrium conditions of comfort.

Precipitations

They affect particularly the roof form. In areas of heavy rainfall or heavy snow level, the vernacular buildings were adapted taking steep solution. The origin of this gesture is found in the constructive use of plant materials, wood or straw, which under prolonged action of the excessive moisture would deteriorate. Throughout the country, climatic conditions and constructive knowledge led to the adoption of roof type structure. There are no constructions with domes or covered patio among the buildings housing architecture. Size guttering or presence of porch, of foișor (gazebo) or cerdac does not meet only the role of sunshine but also that of controlling against precipitation, present in solid or liquid form. Often achieving stone foundations while the superstructure is made of wood or earth indicate the way out to defend the building from direct rain or water leakage resulting from melting snow.

From February until June-July rainfall at the national level is increasing, reaching its maximum level when the summer passes. This period is succeeded by a gradual decrease during the winter. However, where the Mediterranean influence is present in areas such as Banat, Oltenia and seaside, during November–December is been showed a high level of precipitation and a low one in late summer [21].

Summer is the season of maximum precipitation. The Dobrogean areas make exception in this respect. Winter precipitation is much reduced level.

Snow depth is a very important parameter because it results in major impacts on architectural form, especially the roof. Due to low temperatures in winter, snow in the mountains melts snow more difficult for which successive increase the size of the snow. The roof of the high plateau or mountain areas, where precipitation layer is deposited in solid form, presents a sharp slope. They can be assigned to areas with higher thicknesses (75–100cm) corresponding to the Romanian Plain Sub-Carpathian Depression of the Carpathians, the Carpathian foothills, or very large thicknesses, in the mountains above 1000 m altitude, where snow cover exceeding 100 cm [22]. The lower layers of snow (less than 50 cm) can be seen in Dobrogea, Danube Delta, western lowland plains of the country and partly in Transylvania [23]. The average thickness is between 51–75cm and is distributed in the west hills of the country, the centre of the Romanian Plain, Bărăgan, Dobrogea, the plateau areas in Moldova, and most of Transylvania.

The wind

In Romania, the major predisposition of the moving air currents is coming from the west direction, as the effect due to movement of terrestrial weather, from mid-latitudes [24]. At lower altitudes decreases the cause of western winds, their movement being influenced by exposure over mountain peaks and orientation to the predominant air current movements. The prevailing wind directions outside the perimeter of Carpathian mountain chains seek guidance. As is noted in Moldova zone, the predominant direction is northern and north-west. In the presence of various valleys or corridors, wind directions respect their axial orientation. In the south, prevailing winds are east-west course while they differ in Transylvania after the orientation, slope exposure etc.

The form of hipped roofs, prevalent all over the country have the role of capturing cold winds, influencing in the farm the size of the wind calm shadow with a protective role, particularly toward cold winds. There is forming on the north east or west sides, a disposition of the blind walls, without windows, helping to protect the facades facing the opposite direction of cold winds. Small windows do not induce the loss of heat through the convective effect due to the movement of air currents.

Construction layout from a rural zone in a large vegetation area presents a protective effect against cold winds.

In particular, in Moldova appears behind the storage house, a shed and animal housing, which act as a thermal buffer in the way of cold air currents.

Wind insurance fulfils the role of natural ventilation or cooling facilities during the warm season.

Conclusions

Bioclimatic design is now a specific type of approach to contemporary design, within the holistic concept of eco-compatible architecture. For such a matter, the experimental design methodology is an extremely present topic. If the science has reached today unprecedented growth rates, past experience should not be forgotten.

Vernacular architecture, manifests as an intuitive way of adapting to all conditions that influence the user, but also its creator and remains an essential foundation of science knowledge to design. This study has highlighted some aspects of architectural form correlated with the climatic agents. The aim was that of completely understanding the mechanism of formation and maintenance of a relatively simple system compared to the existing urban development, for the valuing and exemplifying the sustainable conception.

In the current discourses, the economy of conventional energy resources is an integral part of architectural design. In an eco-compatible approach in designing of buildings, also as in the assessment process of their impact in terms of sustainability, the energy saving issue is a very important point of view. In this regard, for ensuring microclimatic comfort in the built spaces, the adoption of passive energy systems entails significant energy savings. Proven as valuable strategies in the light of empirical experience over time, bioclimatic principles are using basic rules of physics, for which they are able to provide conceptual guiding lines framework for the architecture design.

Of course, contemporary design touches aspects of a topic of much greater complexity and the assumption of such construction models would be ineffective, since the system of relationships, the complexity of human activities and the space in which they daily take place are subject to corroboration of extremely diverse scientific fields. Understanding the principles of adapting to the conditions of a place is usually knowledge of architecture and an example of interdisciplinary involvement, essential between the architect and climatologist.

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Control Architecture Challenges for the Residential Micro-network Based on Renewable Systems Utilization: A Non-exhaustive Review

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The demand for energy is rising and must be expected to continue to do so in the near future. One of the possible answers to the occurring problems is certainly to raise the efficiency of energy conversion and of usage by "intelligent" buildings or reasonable user habits can contribute to a significant reduction of energy consumption. A second method is the use of renewable energy resources to produce the required secondary energy, such as photovoltaic panels or wind turbines.

A multi source system for habitat can be assimilated with a residential or tertiary micro-network. We deal in this paper with the optimization of adequate applications for the conversion of the renewable forms of energy, for example the energy from solar radiation, wind, biomass, geothermal energy and marine energy.

The proposed issue is primarily a problem of optimizing of electricity exploitation, including sizing aspects; the main objective is the evaluation of renewable energy production capacity that could be associated with a residential area. We present in this paper the current challenges and a short review concerning general control architecture for a micro home network. We deal with the control architecture and algorithms developed for the residential micro-network based on renewable systems utilization.

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Energy management systems for multi-source residential building - non-exhaustive review

Multi source system for residential building

Hybrid power supply connects together all electric supply can be provided by coupling two or more sources of different nature. Hybridization sources could be considered primarily a sizing problem. Applications, like handheld (computers, radios, mobile etc.), transport (electric vehicles) or stationary (independent power supplies, emergency support or assistance), have similarities in the overall profile of load profile: power demands are relatively low, but for occasional or periodic peaks [1].

A proper design of power supply energy of hybrid systems involves an appropriate combination of the main energy source of secondary sources required during peak load. In this context we can introduce the concept of energy source and power source. In certain applications, hybrid systems combines the high energy density elements with high power density elements, thus better responding to changes in consumption. Such a hybrid system has many advantages because it allows to select individual components with smaller size, limiting their operating range to the specific areas characterized by the best efficiency.

The problems associated with hybrid systems vary by different criteria: the application (stationary and transport), the topology (autonomous or connected system to the network), and finally the properties study (dynamic response, load tracking, lifecycle profitability, average efficiency, real-time control).

The habitat, residential and tertiary sector is understood as locations of electrical equipment of sector users. Physical system is considered generally with behavior models characterized in terms of energy applications and services [2]. Multi source for residential building in its broad sense can be treated as a micro or tertiary residential grid. The micro grid is defined as a set of intermittent renewable energy sources as an associated support systems connected to the network in a single connection point, with features incorporated to facilitate integration.

The micro grid has centralized management and can operate connected to the network or insular, in autonomous mode.

Various aspects of micro networks are an important focus of research MicroGrid project in Europe, or the working group CERTS in the United States of America. Pilot projects are accompanied by demonstrators; in France, the platform called PREDIS developed in the research laboratory G2Elab from Grenoble performs a hybrid real-time simulator, a PV generator, a micro turbine, a fuel cell, wind generators emulators, controlled loads, control and surveillance systems [1].

Control Architecture of a Residential Network

Network management is an issue of exploitation and the best way to use existing facilities, under the constraint of ensuring safety. It covers all aspects of demand: stability, security type (N-1), incident management, voltage and frequency adjustment, the program's operating production units.

In particular, residential electrical controls implement the means of production to cover the load on the time scale of tens of minutes. The aim is to produce the power required at a minimum cost, taking into account a set of constraints, physical and environmental security. Electrical network planning consists in determining the infrastructure (the means of production, transmission, distribution and communication) to respond to scenarios of increasing demand for electricity in the long term.

An electrical network is managed from a central station, communications systems ensure the transmission of signals (logic signals indicating the state of circuit breakers, alarms) and measurements (voltage, active and reactive power). This system of data collection and display is generally designated by the acronym SCADA (Supervisory Control and Data Acquisition).

For micro network control architecture there are different levels of architecture. In Fig. 1 we present the variant proposed in [1].

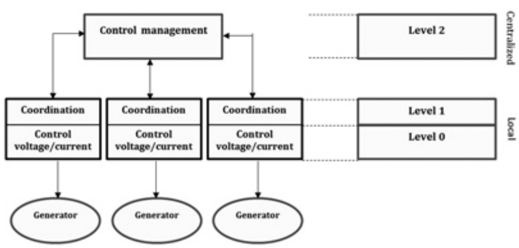

Fig. 1. Control architecture for a micro home network

- Lower-level command (level 0) is local control of voltage and current of each generator (via a power converter usually). These regulators control active and reactive power generation requirements.
- References of these controllers are generated by level 1 dedicated to coordination among generators. In an insular running mode, this level of control carry out the distribution of costs between different generations of micro networks, so as to achieve a balance of power between consumption and production while controlling the main parameters of the micro network (voltage and frequency).
- Finally, there is a centralized management system for higher level (level 2), which is necessary to optimize micro grid running modes in technical, economic or environmental terms. The main function of the management system, based on available information (network status, the availability of generators, consumption forecasts, current rates etc.), is taking the necessary decisions (operating mode, program generation, reference generators, load shedding load etc.) to achieve an optimum.

Supervisor decides first mode, which normally is connected to the network, if a failure or volunteer management system can give the order to change the mode and switch to the insular to reconnect to the network again.

The supervisor will also decide on the next few hours the program generation, the monitoring and observed deviations correction. Finally, the supervisor may, in insular mode, shedding non-critical tasks, if the generating systems are not able to provide all the energy, or may decide the procedures to limit the production of renewable energy, where there is an excess of power [2, 3].

We will focus, in this formalism microgrid residential, only the higher level control functions: coordination of the hybrid system to ensure load tracking (level 1 and 2), then economic optimization functions (level 2).

To better highlight the different control strategies explored, as shown in the diagram from [1], the problem can be deliberately extended to other multisource systems (Fig. 2).

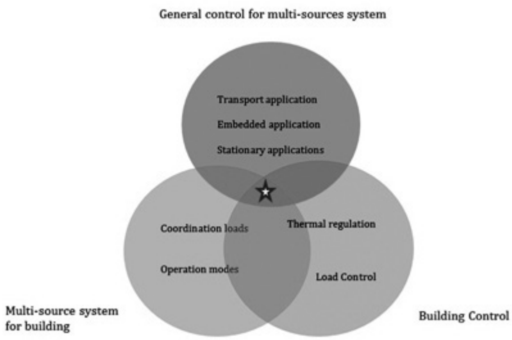

Fig. 2. Different control for multisource systems

Algorithms for micro networks:

System connected to the grid

Optimizing multi-source control systems connected to the network, as treated in the literature, is situated in a sizing of an installation project: given a long-term economic scenario (eg a policy of purchasing power), its control strategy (based on heuristic rules as a result of a deterministic optimization), investment costs and a load profile, we could determine the ideal mix of sources available, which minimizes the investment return. In Figure 3 we present a hybrid production system wind-PV connected to the network associated to an energy storage unit. This architecture is utilized in [4].

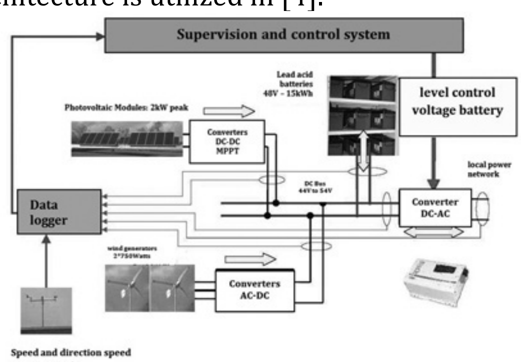

Fig. 3. Synopsis of a small hybrid production system wind-PV connected to the network (energy storage)

Battery storage systems are privileged: they can provide an additional degree in the distribution of power flow; they offer the possibility to save the insular load demand when the network losses are.

Strategies can be based on heuristic rules (export of local production, with a limitation strategy; independent operating scenario; reducing dependence on the main network users [4]) deterministic optimization of production and storage plan [2, 5].

Autonomous Systems

Optimizing multi-source control systems connected to the network are generally placed outside the tariff system: given the need to balance production and consumption, the objective function was to minimize the total cost of production or volume of fuel consumed, in a system with generator.

Without recourse to the network, the system is constrained: a hybrid system with two controllable sources may be controlled only by a single decision variable (the reference source master in a master-slave configuration). This means usually to build a control strategy based on simple heuristic rules [6].

One advantage of generating sources hybridization is sought to improve performance and track dynamic load application. Thus, the issue tracking application load occurs primarily in insular mode, in which all generators should respond in a coordinated manner at a variable load over time: global balance of power must be ensured, while the main parameters (voltage, frequency) are controlled. On the other hand, in the network connection, the superior network level control is responsible for determining the references of current and internal voltage of the generators.

There are two main strategies for the allocation of tasks, using voltage inverters:

control using statism curves and master-slave control [1].

Coordination using statism curves

Coordination of statism curves is applied to electrical networks where participating alternators to frequency and voltage control, sharing total demand of active and reactive power [1]. This function is provided mainly by the speed and voltage regulators of individual units, depending on Pf and QV characteristics (Fig. 4.). This ensures stable operation of several groups connected in parallel. Thus, based on this type of adjustment by statism, enables single cell synchronization network for a reconnection.

Statism is defined in relation to nominal speed, and calculated by:

$$statism = \frac{N_0 - N}{N_0}$$

Where and are respectively the free speed and the speed at full load.

In the insular mode, the equilibrium point reached by the generators following a disturbance can be obtained at a different frequency and voltage of the nominal values. This frequency and voltage error must be corrected by adjusting the statism [7]. Moreover, to optimize the functioning of the microgrid, it is also necessary to vary the statism curves [8, 9]. Fig. 4. highlights the main operating principle of statism presented in [8].

Coordination by master/ slave control:

In this control strategy, there are two operating mods: P / Q mode and V / f mode [10]. In the P / Q mode, the generator controls the active and reactive powers injected into the network. In V / f mode the generator controls the voltage and the frequency respecting the limits imposed by the rules.

In insular mode, the master generator operates in V / f mode, therefore absorbing the differences of power (the load minus other sources), while the other generators, in the slave mode, are working in the P / Q mode injecting power into the grid, the voltage and the frequency of the system being imposed by the main grid [11, 12].

It must be emphasized that the master slave strategy is better suited as a strategy based on statism because of the unprogrammable nature of renewable sources that could characterized a residential microgrid.

However, this control strategy, as opposed to statism strategy requires a fast communication infrastructure in order to respond effectively to operating changes.

In insular mode, depending on the current state of the microgrid and the forecast of the load demand, the management system decide to launch load shedding procedures for the non prioritary loads (charges) if the supply in electricity cannot be ensured. The issue is to ensure the tracking of the demand, considering the random nature of renewable resources, minimizing the differences of power [13]. The command is simple and robust when it is done for example with fuzzy controllers. The disadvantage of this method is that renewable sources are not used to their full potential.

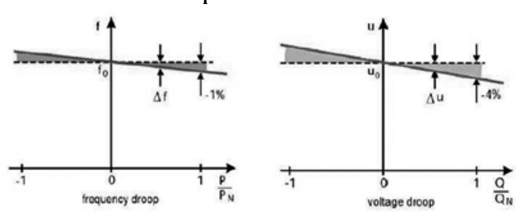

Fig. 4. Operating principle of statism

Pilotage duties in habitat

We will take into consideration the load piloting task wich in the residential scenario is somehow dual to the proposed issue. In particular, we are interested in the direct control of the residential load shedding [1].

Economic optimization of pilotage

As mentioned above, multi-source system for habitat in the broadest sense can be likened to a micro-home network. Economic and energy optimization goal (by supplying energy and services) is the natural approach similar to problems of power grid. Much of the power system optimization algorithms to optimize economic concerns: Economic Dispatch (ED), Unit Commitment (UC) and Optimal Power Flow (OPF) [14].

The common points of the algorithms cited above are:

- The optimization is reduced to a constrained optimization;
- Nature of equality type restrictions: Kirchhoff's laws, energy balance;
- Nature of inequality type restrictions: admissible operating range (limited resources, security).

On the other hand, objective functions can be of different types: economic criteria (total production), minimum deviation and voltage quality.

Economic Dispatch (ED): to ensure the balance of power at the lowest cost, at some point, demand is known, the generators are in operation and costs are given. It is assumed also to have a model that directly links the loss of control variables (active power levels N).

There are some limitations: ED requires convex cost curve, network is neglected (in part), ED algorithm cannot identify units that should be stopped.

Unit Commitment (UC): the main objective is the identification of the generators to be run or stop for a period, taking into account the power spares, restrictions and dynamic start-up costs. This optimization is a mixed discrete / continuous optimization problem. Limitations: the various combinations is reduced, requires a list of priorities.

Optimal Power Flow:

The algorithm takes into account the network structure, security constraints (N, N-1), proper modeling resistive losses, a realistic representation of the problems Q / V [14, 15].

The problem of optimal management of multi-source system would be similar to a classical problem of calculating the optimal production plan a network of power plants (Unit Commitment), reduced to a very small scale. It can indeed neglect the influence of the network, including losses in production efficiency of generators, the operator must decide on plans to stop and start functioning during the controlled generators.

Current state of the algorithms

Direct control methods have been widely used by power companies during the past 20 years, and there is a substantial literature on the existing scheduling algorithms and load shedding strategies [16].

Direct control is one of the possibilities to load piloting : the problem is viewed from the electricity company perspective (point of view) , which reacts to load changes by giving orders to the (their) customers. The adaptive control scenario on the client level has not been yet examined despite the fact that there are initiatives in the United States and Canada which are showing that the load control exercised on a voluntary basis (the initiative of load shedding is left to the initiative of the customer) is quite well accepted [16, 17].

The main objectives of the various direct control algorithms:

- Minimize the peak consumption;

- Minimize total cost of the network manager (production costs for the clients plus penalties paid to load shedding customers);
- Minimize the number of customers asking for load shedding.

The control action is specific and takes into account the group size, the number of control cycles, the time of starting of each control cycle, the length of a period of "off" or "On" (can change every cycle), the total length of control.

In general there are two possibilities for the choice of optimization algorithm:

- Linear Programming [18–21];
- Dynamic programming [22].

Finally, it should be formalized as a mathematical form by modeling the variables and the constraints (restraints).

Summary of management methods:

The choice of control strategies requires a restriction on the load shedding program that may seem artificial [19, 21]. The method of resolution may also require difficult assumptions [20].

Another restrictive assumption concerns the hypothesis of perfect knowledge of the full load curve, and also the load curve for each group. Almost all studies regarding the direct control are placed in a deterministic scenario. The uncertainty is sometimes considered with a weighting factor [23] or by using fuzzy logic.

Some studies, such as in [23], satisfy this restriction and, beyond the simple optimization procedure, propose a complete algorithm designed as a real-time application.

- Methods of forecasting: ARMA models (Autoregressive Moving-Average Model) giving a load curve prediction;
- Optimization Methods: Fuzzy Dynamic Programming;
- Methods of adjustment: the priority rule based on inference heuristic, this method allows the compensation of the differences between the prediction and the real data found.

Conclusions

In the classical acknowledgement, the multi-source system for residential purposes can be assimilated with a residential or tertiary micro-grid.

This paper was achieved like a short review in order to assess the performance of the strategies that could be used in practice, covering the necessary aspects of prediction, optimization and reactivity characteristic of energy consumption of residential areas.

As a first direct consequence, we have considered that the optimal piloting issue for residential purposes must be approached on the highest control level, on long periods of time (hours, days, weeks).

The deterministic approach can be taken into account, if the perfect information of the load and the system characteristics are known, so that will lead to a constrained optimization problem. These approaches can be considered incomplete since they don't allow applicable solutions in real time. Due to the uncertainty on the demand and on its evolution, the design of hybrid control system is achieved through a compromise between performance and robustness, by choosing management algorithm. This compromise is generally not stated clearly, neither justified with alternative approaches.

It has been highlighted that autonomous systems are paradoxically more restrictive because they must achieve the balance production/consumption in every moment without resorting to the network. Therefore, an update of this problem has been made in the much more general thematic of the integration of renewable energy sources into the production systems and distribution of electricity. The guiding line of the actual state of this problematic is made by considering the energy management of hybrid systems and other applications (stationary, land, portable).

Future prospects this work also fit in the new concept „client - producer of electricity", capable, through an optimized control to respond to the fluctuating pricing scenarios. The proposed issue is primarily a problem of optimizing the exploitation of electricity, which reaches of course and dimensioning issues, with the aim of economic valuation of renewable energy production capacity that could be associated with a residential area.

Acknowledgements – The work of NICHITA Mihai was supported by POSDRU Project EFICIENT – ID 61445/2009. Project sponsored by the European Union and the Government of Romania.

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CO_2-emission of a Wood-fired Detached House

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Primary aim of my investigations was to measure the wood consumption of our family house and based on this to calculate its carbon monoxide emission. Moreover, correlations were investigated between the outer air temperature and the wood consumption then results were assessed from local and global points of view.

Between 1st March and 30th November 2010 the quantity in kg of wood burnt and the produced ash was recorded very day. Daily mean temperatures were provided by the National Meteorological Survey. Based on these, the studied period was dissected into 5 sections: spring with continuous heating, spring transitional period, period with no heating, autumn transitional period and autumn period with continuous heating. These periods were discussed and compared in detail. Figures are given to illustrate the amount of wood burnt and the evolving of the daily mean temperatures, then correlation between them was calculated and regression analysis was made. Results revealed that the amount of used wood depended not only on daily mean temperatures but the lifestyle of the family as well. This was analysed in more detail by the Mann-Whitney method. Moisture content of the wood applied for heating was determined by heating. The result was 11.2%.

Bearing in mind the moisture content I have calculated based on the atomic weights that with the burning of 1 kg of dry wood around 1.302 kg carbon dioxide is formed. Based on this I have calculated the amount of CO_2 released into our environment by our house.

Between 1st March and 30th November 2010 in total 5386 kg wood was burnt producing 107.6 kg ash and 7012 kg CO_2 was released into the atmosphere. I calculated that 1 hectare of temperate zone forest binds at least 22t of CO_2 thus our 12.6 hectares of forest is capable of binding several times that amount of CO_2. In case we study the CO_2 emission and binding locally we can state that more CO_2 is bound by our forest than we release by our heating. But if the entire atmosphere is studied, all burnt wood increases CO_2 content as the CO_2 binding capacity of woodlands decreases globally due to deforestation.

Finally ways of saving heating energy in order to reduce carbon dioxide were analysed.

Introduction

Environmental protection principles include “Think global, act local”. Related to this, numerous questions arose in me that is why I chose this topic. I wondered how much CO_2 is emitted and released back into the atmosphere if it is heated by wood. In order to provide appropriate monitoring the examination was carried out in our own detached house. I also investigated the question whether our 12.6 hectares forest can uptake the CO_2 released by our house or not.

Aims

The following issues were investigated in the course of the study:

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- How much wood is consumed by the heating of our detached house? Wat influences this quantity?
- How the amount of wood required by the house varies in different temperature conditions? What are the differences and similarities between the spring and autumn heating periods?
- How could we save heating material without lowering our comfort?
- What degree we overheat the house? How is it possible to reduce this?
- How the quantity of wood used for heating is influenced by the life rhythm of the family?
- How much CO_2 is released back into the atmosphere? How much CO_2 is bond by our forests?
- How heating by wood can be assessed considering the environment from local and global point of views?

Applied methods

Methods applied in the course of the study are listed below, however, their detailed description is given later.

1. Assessing the most important literature related to the topic.
2. Measurement of the consumed wood: Quantity of burnt wood and produced ash was measured between 1st March 2010 and 30th November 2010.
3. Determination of the moisture content of the wood by the ignition method at 150 °C. I measured the weight loss of the wood pieces until weight balance.
4. Systemizing, processing and assessment of the measured data and those provided by the National Meteorological Survey (NMS).
5. Correlation calculation and regression analysis were performed on the data of every studied month and then on the data of the complete database. In this way numbers are obtained on the correlation between the amount of used wood and the outer temperature. Daily mean temperatures were given by the NMS. Moreover, standard deviation is also studied and with the help of the Mann-Whitney method the influence of the habits of the family on the amount of burnt wood is investigated.
6. Calculation of the released CO_2 during our heating based on relative atomic weight considering the moisture content of the wood.
7. Quantity of CO_2 bond by our forests was calculated.
8. Construction of figures and tables applying Microsoft Excel.

The studied family house and its heating system

Building permission for the house was issued on 28th July 1993 and it was completed in August 1996, it has been inhabited since then. Total ground-space of the rooms of the building is 148.4 m^2: ground floor area is 107.2 m^2, attic area is 41.2 m^2.

When the heating system was installed the upper system was constructed to be independent from the lower one primarily from economy point of view. A switch is incorporated into the network with which the upper system can be switched on and off the network. In the heating period all rooms in the ground floor are heated while the attic is only switched on at the weekends when the heating area is increased from 107.2 m^2 to 148.70 m^2 and the cubic metre of air is increased from 394.7 m^3 to 493.6 m^3. Outbuildings are not heated.

Results

Amount of burnt wood and that of produced ash was recorded from 1st March untill 30th November 2010. Daily average of temperature values measured at the meteorological station called Milota Waterworks was used for the study.

On the basis of our heating, the studied period was divided into 5 sections:

1. spring continuous heating period (from 1st March till 27th April),
2. spring transitional period (from 28th April till 20th May) heating free period (between 21st May and 7th September),
3. autumn transitional period (from 8th till 22nd September),
4. autumn continuous heating period (from 23rd September till 30th November).

Monthly heating hours on weekdays, and at weekends:

March and November	at weekends	8-10 hours
	on weekdays	4-6 hours
April and October	at weekends	6-8 hours
	on weekdays	3-5 hours
May and September	at weekends	2-3 hours
	on weekdays	1-2 hours

Relationship between the burnt wood and the outer temperature

Table 1. Results of correlation calculation for the studied months ($p<0.05$)

Month	Mean temperature of heating days (°C)	Amount of burnt wood (kg)	Number of data pairs	Correlation coefficient (r)
March	5.4	1685	31	-0.817
April	11.3	905	26	-0.437
May	12.5	122	5	-0.658
September	13.4	272	9	-0.363
October	7.2	1086	31	-0.283
November	8.1	1306	30	-0.604
Total		5376	132	-0.691

Completing the correlation calculation for the entire studied period the result is $r = -0.691$. This suggests that, regarding the entire period there is a relatively strong correlation between the quantity of used wood and the daily mean temperature values despite that subjective elements caused by the habits of the family reduce correlation.

Results also indicate that the quantity of used wood depends not only on daily mean temperatures but on the life rhythm of the family as well. I assumed that temperature influenced significantly the amount of fuel. Based on the Mann-Whitney test I proved that the habits of the family also influence the quantity of wood used significantly. In order to better understanding weekdays (90 days) and weekends (42 days) were separated.

It can be stated that much more wood was burnt at the weekends, in school breaks and on holidays than on working days as the whole family was at home. More wood was used also when the attic was heated together with the ground floor. In this case the heated area and cubic metre of air were increased therefore in order to reach appropriate temperature in the entire house much more wood has to be burnt.

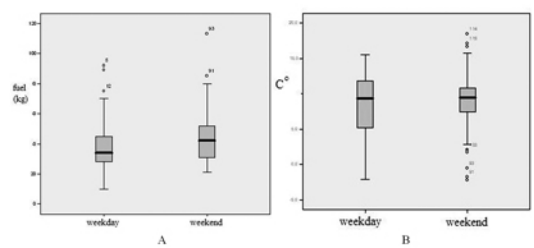


Fig. 1. Application of the Mann-Whitney test on fuel (A) and on temperature (B), on weekdays and at the weekends

Difference between fuel used at the weekends and on weekdays is significant according to the Mann-Whitney test ($p=0.037$; $N=132$). On the other hand, no difference is found in the case of temperature ($p=0.91$; $N=132$), this means that the quantity of used fuel depends greatly on whether the studied day is a weekday or a weekend day.

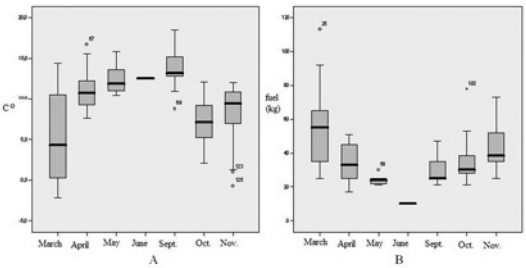


Fig. 2. Standard deviation of temperature (A) and used fuel (B) by months

Fig. 2. (A) presents the standard deviation of temperature according to months. The figure shows only the mean temperature of heating days. Greatest standard deviation appeared in March while smallest was experienced in June as the heating was switched on only one day. Standard deviation of this cannot be interpreted therefore no standard deviation value is obtained. Mean temperatures of the 9 heating days in September were the highest.

Fig. 2. (B) presents the standard deviation of the used fuel according to months. Greatest standard deviation appeared in March. Comparing the two figures it is clear that increasing mean temperatures of heating days follow the decrease of used fuel.

Difference between spring and autumn heating

Spring heating was abandoned at higher temperature than that of the start of the autumn heating. Continuous spring heating was stopped on 27th April at daily mean temperature of 14.1 °C while continuous autumn heating was started on 23rd September at a slightly cooler temperature of 13.4 °C.

I wondered whether there are other differences between the spring and autumn heating or not.

Comparison of the heating in May and in September.

There were five heating days in the last month of spring (May) their mean temperature was 12.5 °C. In total 122 kg wood was consumed. On the contrary, in the first month of autumn heating was on for 9 days and the mean temperature of the heating days was 13.4 °C. In these days 272 kg of wood was burnt. In May temperature over the heating days was more than 1 °C higher than in September. However, if we examine the mean temperatures of the 2 days prior the 5 heating days in May, the result is 16.6 °C. The same for September is as follows. Average of the mean temperatures of 6th and 7th September was 12.9 °C while that of 21st and 22nd September was 12.9 °C. In the autumn months days of mean temperatures around 3°C lower than in the spring months were ahead of the heating days. Over these days our house cooled significantly explaining greater wood consummation in September.

Comparison of heating in April and October.

In April 26 days were heating days over which 905 kg of wood was burnt. In October there were no heating free days, i.e. heating was on over 31 days and in total 1086 kg of wood was placed into the heater. Comparing the monthly mean temperatures, April was almost 4 °C warmer than October explaining greater wood consummation.

The followings were experienced during heating in March and in November.

Heating was on in both moths entirely. Over the 31 days of March 1685 kg of wood was burnt in total while 1306 kg were used over 30 days in November.

Mean temperatures in March were 3 °C lower than in November thus greater wood consummation is explained in March as well.

If an average is calculated from the mean temperatures of the heating days of the spring months the result is 9.7 °C while the same for the autumn months is 9.6 °C. In spring months 2590 kg of wood was burnt over 62 heating days while in autumn months 2664 kg of wood was used over 70 heating days.

The conclusion following the comparison is that there is no significant difference between the autumn and spring heating periods regarding either mean temperatures or used wood. Considering certain months, however, greater differences may appear.

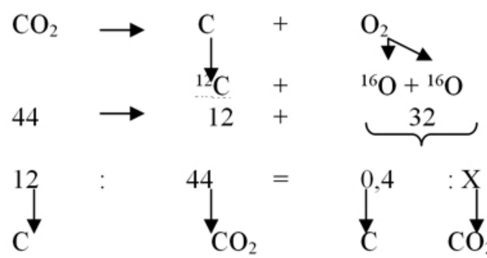
Determination of moisture content and CO_2 emission of the burnt wood

Heating value of wood is strongly dependant on the moisture content. The more moisture the wood contains the less its heating vale will be. Moisture in the wood has to evaporate during burning therefore the higher the moisture content of the wood is the more energy is wasted in the course of heating.

Wet wood with a moisture content of 50% has half the heating value of dried wood with a moisture content of 10%. Burning wet wood is not only uneconomical but it harms the environment as well. As a result of high moisture content burning temperature is smaller as a part of the heat produced by burning is used for evaporating the water content, release of soot and harmful material is increased. Calculation of CO_2 emission will be realistic if related to moisture free wood.

Our detached house is heated by hard wood the average heating value of which varies around 14.8–15.1 MJ/kg [2]. Mostly acacia is used, however, wood of apple, nut, plum and maple trees are also burnt. Generally firewood is left on the free air drying for one year then it is stored in the cellar. Heating value of the air dried acacia is 14.9 MJ/kg ((www.carborobot.hu).

Chemical analysis revealed that moisture free dry material composition varies in slight degree in different wood types showing C content of around 38–42% therefore 40% of carbon content is applied in further calculations (0.4 in the proportion).



$$X = \frac{44 \times 0{,}4}{12} = 1{,}466$$

CAr = 12 (Ar: relative atom weight dimensionless No.) OAr = 16. Using this it can be calculated that the molecule weight of CO2 is 44/mol.

Thus 1.466 kg CO_2 is produced when 1 kg of water free wood is burnt. In order, however, to determine the quantity of CO_2 actually released into the atmosphere the moisture content of the firewood left drying for a long time period (around one year) had to be determined. Six pieces of wood of the size used most frequently for heating was taken. Total weight of the 6 wood pieces was 10.99 kg. The wood pieces were placed into the oven of our gas cooker that was heated up to 150 °C. The first measurement was performed one hour after placing the wood into the oven, then weight loss was measured every half hour. As weight loss ceased practically after 4 hours I finished measuring. Results are given in Table 2.

Table 2. Weight decrease of dry firewood at a temperature of 150 °C
(Change of the weight of wood pieces (kg) at different measurement times)

	0 min.	60 min.	90 min.	120 min.	150 min.	180 min.	210 min.	240 min.
1.	1.47	1.43	1.39	1.36	1.35	1.33	1.32	1.32
2.	1.59	1.51	1.46	1.43	1.37	1.34	1.33	1.32
3.	1.28	1.21	1.18	1.16	1.14	1.11	1.11	1.11
4.	2.2	2.15	2.1	2.06	2.02	1.97	1.98	1.97
5.	1.83	1.77	1.73	1.71	1.71	1.71	1.71	1.71
6.	2.62	2.55	2.49	2.45	2.41	2.35	2.33	2.32
Σ	10.99	10.62	10.35	10.17	10.00	9.80	9.78	9.76

Weight of the 10.99 kg of wood was reduced by 11.2 % (1.23 kg) that equals the moisture evaporated from it. From 1000 g of wood 112 g of moisture was evaporated, in this way 888 g of dry wood remained. Its 40 % carbon content is 355.2 g. Calculating to water free wood the carbon content is 35.52 %. Based on this the quantity of CO_2 released is calculated as follows:

$$12 : 44 = 355.2 : X \qquad (2)$$

$$\frac{15623}{12} = 1302$$

Thus in the course of burning 1 kg of dried wood still containing 11.2% moisture 1.302 kg CO_2 is released into the atmosphere.

Quantity of CO_2 released into the atmosphere in the course of our heating

Table 3. Quantity of CO2 released into the atmosphere in the course of the heating of our house between March and November 2010
(Source: Own measurements and calculations)

Month	Quantity of burnt wood (kg)	Quantity of produced CO_2 (kg)
March	1685	2194
April	905	1178
May	122	159
June	10	13
September	272	354
October	1086	1414
November	1306	1700
Total	5386	7012

In the studied period between 1st March and 30th November in total 5386 kg of wood was burnt releasing 7012 kg CO_2 into the atmosphere, i.e. around 7 tons. According to the census of 2001 4 064 653 flats are found in Hungary and based on the data of Energy-center Nonprofit Company. 20% of these flats (around 800,000 flats) heat by wood. If we assume that around similar amount of wood is used in these flats as well (assuming similar ground-space, cubic metre of air, consumption habits and insulation for these flats) then in Hungary a total amount of 5.6 million tons CO_2 is emitted into the atmosphere as a result of heating by wood in the given time period. This includes not the 3 coldest winter months, however, it is likely that our family uses more wood than the average would be therefore the estimate seems to be justified. If we think further and presume that 1/10 of flats and houses in the World (around 100,000,000 houses) are heated by wood and only half of the amount of wood is burnt over a year than our family used for 6 months then a total of 350 million tons of carbon dioxide is released into the atmosphere. These are of course rough estimates as the intensity of heating is much different in various parts of the World. Considering tropical climate no heating is required, although heat is used for cooking.

When our 5386 kg of wood was burnt 107.6 kg ash was produced and that is 1.99% of the burnt wood.

Significance of forests

Before my measurement results are assessed the diverse functions of forests have to be mentioned. Forest is the source of life for the Earth and for man living on it. It is a biocenosis and a habitat depending on natural factors and human interference. Forest is the most developed biocenosis of the Earth involving micro-organisms living in the soil, moss, fungi, herbs and bushes together with lower and higher animals as well.

Most important effects of forest:

- largest carbon dioxide consumer (carbon binding) and oxygen producer,
- largest organic material producer, source of wood as a raw-material and re-productable energy resource together with numerous products,
- important controller of the water budget of the Earth,
- influence on meso- and macro-climate,
- almost the sole place of continuous food chain support,
- reducer of several disadvantageous environmental effects,
- has unique health and regenerating effects,
- its welfare, cultural, aesthetic effects are essential.

Our natural forests belong, in theory, to renewable energy resources, however, in practice they are only conditionally renewable. They can be depleted if used at greater rate than their renewable capacity [3].

Forests have very important role in the CO_2 circulation of the Earth. Trees incorporate large quantities of carbon dioxide into their own organism therefore deforestation influence CO_2 circle adversely in two ways.

- On the one hand, deforestation (even if different vegetation is planted in their place) reduces CO_2 binding significantly.
- On the other hand, the major part of the carbon from the exploited trees will be returned to the atmosphere sooner or later.

Carbon surplus in the atmosphere due to forest firing is estimated to be around 1 billion tons per year [4]

Conclusion

CO_2 binding of our forests and CO_2 emission of our heating

My family own a total of 12.6 hectares of forest, the CO_2 binding of which was calculated as follows. Net average productivity of temperate climate forests in carbon [5] is around 600–2500 gCm-2year-1. This carbon is originated from the atmospheric CO2. If the smallest value (600 gCm-2year-1) is considered that equals the binding of 2199.96 g CO_2. Calculated with 2200 g the result is that 1 ha forest binds 22 tons CO_2 over a year from the atmosphere (this is the “swallowing function” of forests). The ~7 tons emission of our house together with a similar amount in the three cold months (14 tons in total) surely exceed not this value. As we own 12.6 ha forest it seems sure that we have reserves in CO_2 binding.

If CO2 binding is studied locally, it can be stated that our forests bind more CO_2 than we release via our heating. On the other hand, if we examine the whole atmosphere, all burnt trees increase CO_2 content and the CO_2 binding capacity of woodlands is reduced due to deforestation.

Possibilities of reducing our CO_2 emission

Saving energy also means reducing the total applied energy. Using less energy brings numerous advantages, money can be saved and less load is released into the environment. In order to extract energy valuable natural resources have to be utilized. Therefore the less energy we use the more we can preserve these resources contributing to their long-term protection.

How is it possible to save energy in our family house?

- Installing new doors and windows. Present doors and windows are made of wood. Glazing is made by heat insulating glass but the heat transmitting coefficient of the structure is k ` 3 W/m2 °C. Nowadays 0.9–1.3 W/m^2 °C is considered appropriate as the smaller this value is the better heat insulation will be.
- Wall insulation. The amount of released heat across the surface of a building is an important characteristic. This value is less than 360 MJ/m^2 in the case of buildings with modern heat insulation. The main walls are made of RÁBA hollow blocks composed of class ÉT F. 5. I (silicate) blocks. Thickness of these is 30 cm with 5 cm mortar. Currently walls are not insulated, however, their insulation is among our plans for the future.
- Temporary of permanent switching off heating. This is a rather theoretical possibility for the following reasons. Saving heating energy could be reached by switching off heating in the 2 rooms not used on weekdays when the children are not at home. This is not applied for two reasons. First, rooms would cool too much over five days and it would be difficult to re-heat them. Second, when the weather is bad washed cloths are hung up in these two rooms
- If air temperature in the house was decreased by 1-2 °C our comfort would not be reduced but heating energy (i.e. firewood) would be saved.

Acknowledgement – My sincere thanks are expressed hereby to Prof. Dr. Attila Kerényi, my supervisor for providing all that was required to carry out my work successfully and to write the publication. I thank him for his willing, unselfish support, valuable professional advices, guidance and review of the manuscript.

I also thank Dr. Szilárd Szabó and Tamás Tóth for their scientific advices and willing support in completing the research.

Thanks are also due to the former chair of the National Meteorological Survey, Prof. Dr. László Bozó and head of department Beáta Révész for providing me with the necessary data essential for the research.

Last but not the least I am grateful to my family who carried out necessary measurements conscientious in my absence.

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Impact of Energy Storage Systems on Clean Industry

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Energy consumption is rapidly growing worldwide. How fossil fuels are becoming fewer, there is a tendency to increase renewable energy use. For developing and implementing new technologies in this direction, investments in research remain a key growth factor, because many technologies present technical limitations to practical use. Many existing clean energy technologies cannot be compared with coal energy, who is used as the current benchmark when is evaluated the feasibility. Subsidies are an important key of the renewable energy technologies, but if these technologies are unable to develop long-term comparables efficiency, they run the risk of being relegated to niche products. The possibility of storing electrical energy exist from long time but storage methods are still the weakest link of the energy domain, and in the same time is a key element for the growth of renewable energies. More than this, if the energy source is intermittent and located in an isolated area which cannot be connected to the distribution grid, storage becomes crucial. In this paper are given some issues about the European energy policy, renewable energy in the next years and the importance of developing electrical energy storage systems, both long term and short term.

Keywords: renewable energy, EU energy policy, energy storage technologies, supercapacitors

Introduction

This article presents an ample study of the European renewable energy market and new energy trends in the next years under new policies adopted by the EU.

Few years ago (2008), European Union (EU) adopted an integrate energy and climate change policy with big targets for next year's which includes [1]:

1. To cut greenhouse gases by 20 per cent;
2. Until 2020, 20 per cent of energy must come from renewable sources (winds, solar, biomass, geothermal, tides and other natural elements);
3. The reduction with 20 per cent of energy consumption through increasing energy efficiency by 2020.

Thanks to these new energy policies, the renewable industry has a huge impact

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on global economic growth. Even if in important markets like Germany, France, Italy or Spain the feed-in tariffs was reduced, investments in renewable energy continue to be extremely attractive [2].

Regarding feed-in tariffs European Energy Commissioner, Guenther Oettinger, has said that "the EU needs a harmonized feed-in tariff to boost investment in renewable energy technologies" [3]. He praised the German Renewable Energy Sources for guaranteeing "a fair price" for renewable energy, and stressed that because of this now Germany is the world's biggest solar market and represents a model for similar schemes that will be applied elsewhere in Europe [3].

Currently some company in the renewable market are continuing to face financing difficulties but this representing an opportunity for many investors especially that, compared with other industry sectors, banks have been relatively willing to finance transactions in the renewable energy sector, attracted by long-term stable income and government involvement [2].

Energy storage technology

Electrical energy is an "invisible and omnipresent convenience" in our time and electricity consumption increases by the day. Considering the fossil fuel crisis that gets worse over time, new technologies in the energy sector should focus on renewable energy use but, unfortunately, at present not all technologies can be widely implemented because of technical disadvantages or involves costs too high. Some of these technical disadvantages of clean energy technologies can be avoided by using energy storage systems, and here we can cite, for example, the use of storage systems to avoid voltage sags and break in service of local distribution grids. An overview of systems and energy storage techniques can be found in Table 1 [4–6].

Many of the storage devices and technologies presented in the table above are still developing, which means that their operation in the near future will be improved and their integration in the energy sector will be easily.

Energy storage systems and renewable generation

Developing and implementing new energy storage devices, has a great significance for economic perspective, hence the idea that is needed to implement this technology on industrial scale. The main reasons for that storage system have a great impact on clean energy market, and we can tell to the whole economy, are found in Figure 1 [7, 8].

Because of these, storage technologies have a huge financial impact on the utility sector and customers can expect reduced financial losses due to outages and poor power quality, and more than these, they can also improve the return on renewable energy generation investments and reduce end-user electricity costs. For energy storage market is expected that the investment in the utility sector to grow by 15.8% per year which means over $10 billion in 2015 to global level [8].

Table 1. Energy storage systems

Storage technologies	Method	Advantages	Disadvantages
Pumped hydro storage (PHS)	Stores energy in the form of water, pumped from a lower elevation reservoir to a higher elevation	High capacity, low cost	Requires special area
Thermal energy storage (TES)	Store energy in a thermal reservoir for later reuse	They can be employed to balance energy demand between day time and night time	Requires special area
Compressed air energy storage (CAES)	Compression of air to be used later as an energy source	High capacity, low cost	Requires special area, need gas fuel
Energy storage coupled with natural gas storage (NGS)	Couple underground natural gas storage with electricity storage	Well-developed method	Requires special area, need gas fuel
Energy storage using flow batteries (FBES)	Two-electrolyte system in which the chemical compounds used for energy storage are in liquid state, in solution with the electrolyte	High capacity, independent power and energy ratings	Low energy density
Fuel cells-Hydrogen energy storage (FC-HES)	Convert hydrogen directly into electricity	Fuel cells are self-contained, power-generation devices that are able to produce reliable electricity for residential, commercial, industrial and transportation applications	Are very expensive, and they are energy losers because it costs more to produce hydrogen than is earned by using hydrogen in fuel cells
Chemical storage	Transform chemical energy generated by electrochemical reactions into electrical energy and vice versa	Generally, low capital cost	Limited cycle life
Flywheel energy storage (FES)	Energy is stored by causing a disk or rotor to spin on its axis. Stored energy is proportional to the flywheel's mass and the square of its rotational speed	High power	Low energy density
Superconducting magnetic energy storage (SMES)	Energy is stored within a magnet that is capable of releasing megawatts of power within a fraction of a cycle to replace a sudden loss in line power	High power	Low energy density, high production cost
Supercapacitors	The storage method is a cross between a capacitor and an electro-chemical battery and are used special electrodes and some type of electrolyte	Virtually unlimited cycle life, low impedance, rapid charging, simple charge methods, cost-effective energy storage	Unable to use the full energy spectrum, low energy, low voltages density, high self-discharge

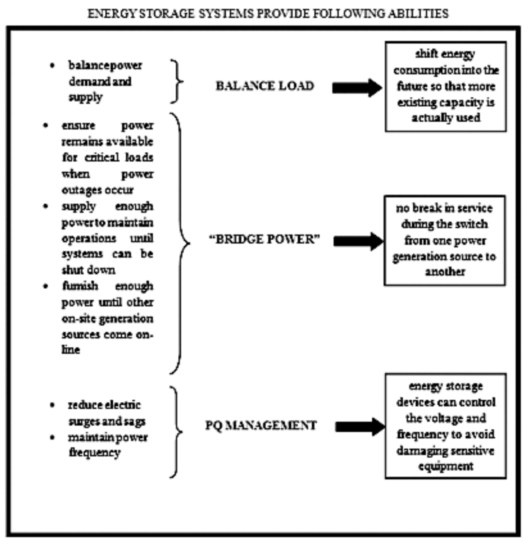

Fig. 1. The "skills" of energy storage systems

Example of reducing the voltage sags using storage devices

As it is stated above (see Fig. 1.), one of the many qualities of storage systems, and here we are talking about short-term storage systems, is that they can generate energy when is necessary. Moreover, the voltage sags, which have a huge negative impact especially for industrial equipment, can be reduced by using short-term storage devices. This application has been demonstrated using a model generated in Matlab / Simulink. This model was presented in a previous paper [10]. The mentioned application refers to reducing the voltage sags arising from the coupling a large load to a micro-grid. A micro-grid is an essentially smaller version of the larger electric grid which can be easily subjects to disturbances and are designed to serve localized electric loads [9].

We noticed via simulation that, following the coupling of large load, voltage drops to a value of 240 V, which represents the appearance of a voltage sag, and returns to initial value (320 V) when the load is not connected to the network (see Fig. 2.) [10].

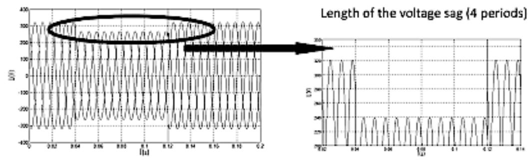

Fig. 2. Voltage sags arising from the coupling a large load to the micro-grid [10]

The simulation has shown, that it exists a possible solution to reducing voltage sags into a micro-grid is by using an active power filter inside which are two blocks of storage devices with a large capacity (see Fig. 3).

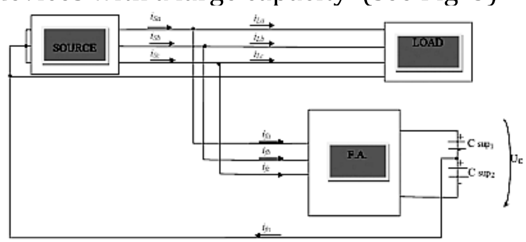

Figure 3. Block diagram of the model designed to reduce voltage sags [10]

There have been done simulations of voltage sags with durations of 20 ms (1 period) until 1 s (50 periods). By using capacitors with very high value of capacity we were obtain, via simulations, a mitigating of voltage dips.

In Fig. 4 it can be see a reduction in voltage sags with length of 1 period (0.04–0.06 s) by using two storage blocks with capacity of 0.3 F each [10].

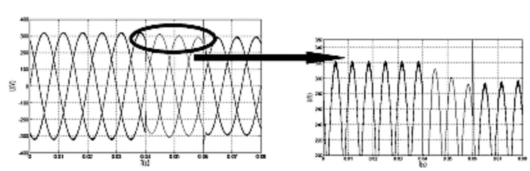

Fig. 4. Variation of voltage U=f(T) using two storage blocks with capacity of 0.3 F each [10]

Reducing the voltage sags is a important topics especially in the industry sector in which they place great economic losses due to voltage sags. During the voltage sags the production lines can be interrupt and the resume of production process represent some additional costs which may be avoided by implementing new technology.

Conclusions

Following the ample study made of recent information on renewable energy market in Europe, we can estimate that due to the new policy adopted by the EU in the next period will be the largest investment in clean energy. Although over time were tested and implemented on the large-scale, renewable energy technologies is still an open research area and some of the disadvantages that arise in local and independent distribution networks can be avoided by using energy storage technologies. Most important benefits offer by energy storage solutions are that they can improved flexibility for grid operators, can increased national energy security, and reduced environmental impact. An example is the reducing of voltage sags by using an active-power conditioner in whose construction are two storage blocks. Via simulation, we obtained a mitigation of voltage sags with duration of 20 ms until 1 s. We already know that the possibility of storing electrical energy exist, whenever and wherever they are needed and in any quantity but the cost for implementation new technologies in energy sectors is a major drawback.

Acknowledgements – The author acknowledges the partly financial support of the grant POSDRU 6/1.5/S/15,6583, SIMBAD.

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Biofuels – a challenge for the XXI-st millennium Energia Transylvaniae handbook, Collegium Geographicum special issue

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Biofuels production becomes actually a necessity recognized by the European Commission that fixed a target of 10% till 2020. The paper presents the concept developed by the authors on biodiesel producing & use in an integrate system adaptable for agricultural farms in a decentralized manner. Different elements (key actions) of the design chain are analyzed in respect of energy efficiency and environment protection.

The study pointed out that Romanian agriculture has all the necessary conditions to develop a sustainable biodiesel production & use and a network of farms working independently of fossil fuels and supplying the biodiesel for the engines used in the protected areas.

Achieving this target imposes the development of governmental financial support schemes. The proposed biofuel integrate system has been already implemented some (unfortunately few) farms.

Keywords: bioenergy, biofuels, biomass

Introduction

Energy efficiency and renewable energy are said to be the twin pillars of sustainable energy policy. In many countries energy efficiency is also seen to have a national security benefit because it can be used to reduce the level of energy imports from foreign countries and may slow down the rate at which domestic energy resources are depleted. Both strategies must be developed concurrently in order to stabilize and reduce CO_2 emissions [1].

According to the demands of the technological development and the life quality increasing, during the last 50 years, global consumption of commercial energy has risen more than fourfold, far outpacing

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the rise in population and all this energy comes from natural resources whether fossil fuels such as coal and oil, living resources such as timber and biomass, nuclear fuel such as uranium, or renewable resources such as flowing water and wind and the power of the sun.

A generation ago, there was concern that fossil fuels would run out, plunging the world into an energy crisis. Today the fear is that their continued use might be wrecking the global climate by emitting carbon dioxide (CO_2) as we burn carbon-containing fuels. This anxiety is substantially increased in view of the considerable unmet demand for energy in the developing world. It is estimated that since 1751 roughly 283 billion tons of carbon have been released to the atmosphere from the consumption of fossil fuels and cement production. Half of these emissions have occurred since the mid 1970s. The 2000 global, fossil-fuel CO2 emission estimate, 6611 million metric tons of carbon, represents a 1.8% increase from 1999. The average annual fossil-fuel release for the decade 1990–1999 was 6.35 billion tons of carbon. As of October 2010, carbon dioxide in the Earth's atmosphere is at a concentration of 388 ppm by volume.

Exposure to air pollution is associated with numerous effects on human health, including respiratory problems, hospitalization for heart or lung diseases, and even premature death. Air pollution can also significantly affect ecosystems. For example, ground-level ozone has been associated with reductions of agricultural and commercial forest yields, and airborne releases of NOx are one of the largest sources of nitrogen pollution in certain water bodies. In this context the use of "clean" fuels for the internal combustion engines is more than a desire is a necessity. Rudolf Diesel, the father of the compression combustion engines, has foreseen the biofuels use. So, in 1900 he presented at the World Exhibition from Paris an engine working with peanut oil. In the same time, Henry Ford developed his famous FORD T fuelled with bioethanol [2].

By economical considerations the biofuels use was abandoned till the beginning of, 70 when the petroleum crisis putted on table the problem alternative fuels.

Under the pressure of the XXI century environmental demands (expressed synthetically in the Kyoto Protocol that was signed by more than 160 countries) the use of biofuels in the case of diesel engines has been reconsidered, especially for the engines working in the most protected areas as communal domains, agriculture, forestry and tourist regions (including lakes for nautical sports).

The European Parliament resolution of 4 February 2009 on "2050: The future begins today – Recommendations for the EU's future integrated policy on climate change" (2008/2105(INI)) – sets out a range of measures that should be taken in order to reduce greenhouse gas emissions by 25–40% by 2020 and a reduction of at least 80% by 2050. The European strategy for renewable energy sources identifies bioenergy as the most important renewable energy source for the future: a source of cleaner, more secure and sustainable power for Europe.

The Commission report advocates that EU and Members States should invest in research on advanced biofuels, among other technologies.

So, the current policy on biofuels must be seen in a global perspective, where on the one hand there is growing competition for productive land and on the other there is an increasing need for renewable energy, in particular in the transport sector. The production of biomass offers many developing countries new economic opportunities for energy production and as a fuel, and will make them less dependent on energy imports, provided that such production is sustainable and does not lead, for example, to monocultures or to competition as regards food production.

With a production growth of 17% in 2009 with respect to 2008, the European Union remains the major producer of biodiesel in the world. In 2009, biodiesel production in the EU reached 10'187 Ml (i.e. 55–60% of the world production).

In Romania, the theme of biofuels has been considered as a major research direction since 1984, when started the first important projects upon vegetable oil, bioethanol and biogas. After 1990 the researches have witnessed a continuous development. An important step forward was done by the establishment in 2002, in Cluj-Napoca, of the BIOCOMB Research Group. It is a complex research team including scientists from different domains as: mechanical engineers, chemists, agronomists, environmental engineers, economists, etc. from the Research Institute for Analytical Instrumentation, Technical University and University of Agricultural Sciences. By the work done and the quality of the results the research group become a pole of excellence in the field, leading most of the research projects dedicated to bioenergy. In the same time, the team has designed the Romanian Biofuels Strategy and the Biomass Action Plan.

The researches were focus on the all four biofuels generations in an integrate manner, from the raw materials productions to the end users and determining the impacts: environmental, social and economical ones.

Integrate system for biodiesel production and use

Biomass resources

The integrate system for biodiesel production and use (Fig. 1.) includes four major steps: raw material production, processing faze, end using and co-products capitalization.

Biomass is derived from different types of organic matter: energy plants (oilseeds, plants containing sugar) and forestry, agricultural or urban waste including wood and household waste [1, 3]. Biomass can be used for heating, for producing electricity and for transport biofuels. Biomass can be solid (plants, wood, straw and other plants), gaseous (from organic waste, landfill waste) or liquid (derived from crops such as wheat, rapeseed, soy, or from lignocellulosic material).

A wide range of feedstocks are available globally for biofuel production including energy crops (e.g. Miscanthus, Jatropha, Short Rotation Copice), wastes (e.g. waste oils, food processing wastes etc.), agricultural residues (straw, corn stover etc.), forestry residues and novel feestocks, such as algae.

The impacts of growing populations and climate change, mean there is increasing local and global competition for land, feedstocks and water for food production (crops and livestock), non-food crops (e.g. plant oils for soap production, timber for construction), and bioenergy (heat and power). At the same time, biodiversity (species of plants and animals) need to be conserved, and forested areas must be protected as they act as importrant habitats and carbon sinks. In other words, the forests store large amounts of carbon in vegetation and soil. If areas are cleared for logging, grazing, crop production or roads, the carbon is released into the atmosphere and habitat is lost. In order to ensure that communities, biodiversity and land are protected a number of certification schemes and sustainability initiatives have been put in place for biofuels.

Agriculture is an efficient energy provider, by converting the solar energy during the photosynthesis in biomass energy. Part of the harvest biomass can used for different biofuels production covering the fuel for technological & domestic necessities in the farms.

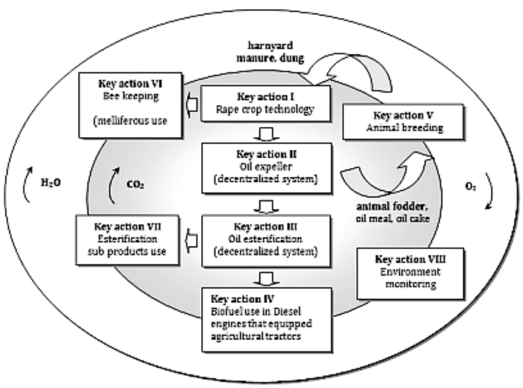

Fig. 1. Biofuel producing & use integrate system

Regarding the raw material for biofuels production Romania has a great potential: the country agricultural surface includes 9.5 million ha arable land of high quality from which only 6.35 million ha were taken in account during the accession agreements. The country pedoclimaterical conditions are favourable for most of the oil crops.

There are about 1700 plants that can offer an oil suitable for use as fuel in the internal combustion engines. From these only 72 can represent a commercial interest. According to the natural conditions for agriculture from Romania, the winter rapeseed oil (WRO) and its methyl ester (RME) represents one of the best choices for the alternative fuels production.

The rape crop requires a precise technology that includes high level seedbed preparation, low/medium level of chemical treatments and high quality harvesting combines. The crop yield varies between 2,5 and 3,2 t/ha.

The actual gross energy consumption for rape cultivation including fertilizers and pesticides corresponds to the general average in farming excluding fertilizers and pesticides. An increase in the rape production area will therefore not increase the total gross energy consumption in agriculture.

Oil expeller & esterification

Unlike ethanol, which is an alcohol, biodiesel is an ester that can be made from several types of oils such as soybean, rapeseed, and vegetable or animal fats. Through a process called transesterification, organically derived oils are combined with alcohol (ethanol or methanol) and chemically altered to form fatty esters such as ethyl or methyl ester (see Fig. 2.). The biomass-derived ethyl or methyl esters can be blended with conventional diesel fuel or used as a neat fuel (100% biodiesel).

The cold pressed rape seed oil presents the energetically and environmentally best alternative to fossil diesel with a strongly positive energy and CO_2 balance. The use of rape seed oil for transport can substitute, after a minor modification of the engine, the agricultural sector’s own fuel consumption. The oil presents no fire and health hazards and it is unpolluting. The oil is pressed in an inexpensive plant with low energy consumption, and the whole production can take place at the individual farm so the fodder cakes can be used on site or be sold locally.

The physical & chemical characteristics of biodiesel obtained from rapeseed oil are according the European (EN 14214) and DIN Norms (see Table 1.).

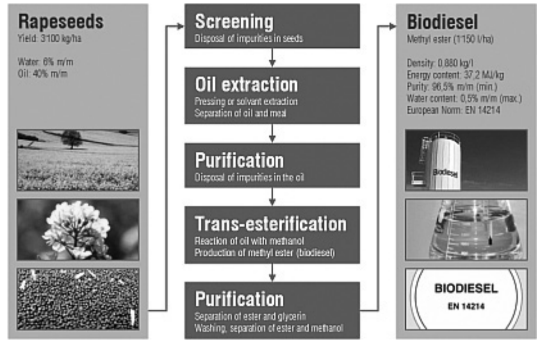

Fig. 2. General scheme of biodiesel production from rapeseeds (after Swiss Biofuels TP)

Table 1. Physical and chemical characteristics of biodiesel obtained

Property	Units	Value	
		Experimental	Standard DIN 51606
Density at 20°C	g/cm3	0.880	0.860-0.900
Kinematic viscosity at 20°C	mm2/s	6.30	3.50-5.00
Flash point Pensky-Martens	°C	184	≥100
Water content	%	0.02	<0.03
Methanol content	%	0.20	<0.30
Free glycerine content	%	0.02	<0.02
Ash content	%	<0.01	<0.01
Sulphur content	%	<0.01	<0.02
Cetane index	-	51	≥51
Lower calorific capacity	kcal/kg	9000	-

It can be estimated that at an oil production of 580 000 tons corresponds to 604 million liters rape seed oil equaling 580 million liters of diesel (this amounts about 32 TJ).

Co-products

The biodiesel production system generates several co-products that can be capitalized, increasing the whole chain efficiency [2]. The secondary system product is the rape cake that can be used successfully in the animal breeding sector. The fodder value and energy content in rape cakes from cold pressing of rape seed oil are presented in the table 2 and table 3. A fodder cake production of 560 000 tons equals 623 million fodder units (FU), 20% of the total consumption of protein fodder of 3131 million FU. We can estimate that by cultivation of winter rape, the total fuel consumption of the Romanian agricultural sector could be covered on a good 18% of the arable area along with covering 25% of the protein fodder consumption in animal husbandry and about 80% of agriculture's total gross energy consumption. Very interesting is the melliferous use of rape crop in bee keeping, this being an important component of the Romanian agriculture (for centuries) and honey an important export product.

Table 3. Rape cakes energy content

Energy content in rape cakes, cold pressing of rape seed oil			Energy MJ/kg rape cake
Kind	% of solids	Energy, MJ/kg	
Protein	33.7	23.9	8.05
Fat	14.6	39.8	5.81
Hydrocarbons	44.6	17.6	7.85
Total solids	92.9		21.71
Total at 89% solids			19.32

End use

The use of biodisel for fuelling the internal combustion engines that are equiping the tractors that are mainly used in Romania was tested on special test benches (Fig. 3.).

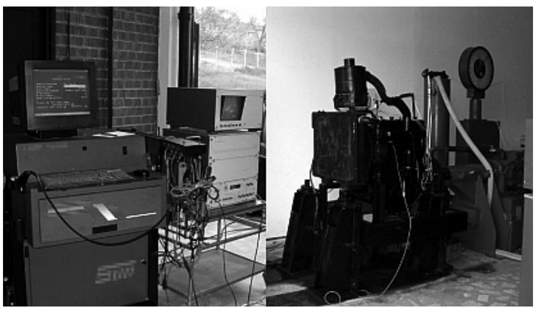

Fig. 3. Testing the biodiesel use

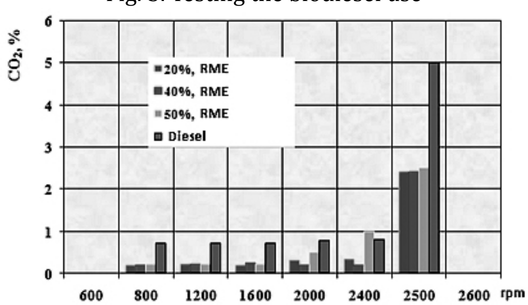

Fig. 4. Impact of biodiesel on the SAVIEM engine emissions

The tests carried on have demonstrated that the use of biodiesel contributes significantly to the pollution reduction (see Fig. 4.).

Conclusions

The study carried on pointed out some conclusions from which the most important are considered to be:

1) The biodiesel production and use must be analysed in an integrate manner determining the energy and environmental efficiency.
2) The biodiesel use can contribute to the pollution reduction.
3) Renewable energies will come in operation step by step when they become competitive or they have the right support from the governments.
4) According to the natural conditions for agriculture from Romania, the winter rapeseed oil (WRO) and its methyl ester (RME) represents the best choice of the alternative fuels.
5) All the integrate system fazes are suitable for farm implementing.

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