IMPLEMENTATION OF THE FIRST PILOT STATION DELIVERING ELECTRIC ENERGY INTO NATIONAL SYSTEM FROM PHOTOVOLTAIC

Victorita RADULESCU[1], Gheorghe CRISTEA[2], Alexandra RADULESCU [3]

The main objective of the project was to realise and to implement a pilot station capable to produce electric energy, delivered into national system from photovoltaic. First was selected an optimum area, from the zone I, considered one of the best economically speaking for our country; some measurements during a whole year considering the solar radiation, temperatures, etc. were made. During time, many tests were realised to establish the optimum system for solar cells, optimum angle of position, geographical orientation, optimum number of rows, optimum economically aspects. For each tested solution were made numerical modelling and simulations of produced energy, establishing benefits (considering produced electric energy and total costs.

A Pilot Station was realised and implemented into the selected area. First was tested the produced electric energy and stored into batteries for two weeks; after that the energy was delivered into national system. During time a data base of on-line measurements was created, necessary for further developments. Some conclusions are presented and further possibilities of improvement the future performances.

Keywords: solar cells, photovoltaic, on-line measurement, data-base

1. Introduction

In the actual context EU decides to reduce during 2008-2010 the pollutant emission with 8% compared with year 1995. Some specific documents concerning principal solutions are mentioned into international documents as: Green Carte, White Carte, the EC Parliament Normative and Border 2001/77/CE, 2002/91/CE, 2004/8/CE, etc. The EC Parliament Normative and Border 2001/77/CE refers at promoting renewable resources on intern market of electricity and imposes to each country member EU an increase of the produced energy from renewable resources till 12.5% from total energy. The directive 2002/91/CE refers at energetic performance of buildings, and imposes rules to be taken accounting external climate conditions and internal comfort in buildings rehabilitations, in conformity of energetic efficiency. The Directive 2004/8/CE refers at promotion of cogeneration based on utile demand of heat energy on intern market in

[1] Prof., Power Engineering Faculty, University "Politehnica" of Bucharest, Romania
[2] Eng., Institute of Research and Design for Electrotechnic, Bucharest, Romania
[3] Eng. Master Student, University "Politehnica" of Bucharest, Eng. SC ELCEN SA, Bucharest

conformity with security in implementation of policies concerning climate changes. The cogeneration must be introduced in internal market of energy to assure a high efficiency of price of produced energy. The EU decides that "Produced electric energy from renewable resources, on unique market" represents a main objective of increasing of utilisation of renewable resources from 14% to 22% till 2010 into all EU countries.

Each country has a target (considering the consumption of electric energy produced from renewable resources reported at total brut consumption of energy) to introduce some specific laws as financial scheme of support of investment.

The renewable resources assure an improvement of systematic energetic internal supply and a limitation of energy import, in condition of a durable development of each national economy. These tasks are realised always into national economic context by implementing local and international policies of energetic conservation, increase of efficiency and superior utilisation of each renewable resources.

In Table 1 are presented some representative values for some European countries as obtained electric energy from renewable resources, compared year 1997 (effective and in percent) and 2010 as objective.

Table 1

Effective and Objective for utilisation of renewable resources

	Country	1997 RR (TWh)	1997 RR (%)	2010 RR (%)
1.	Belgium	0,86	1,1	6,0
2.	Denmark	3,21	8,7	29,0
3.	Germany	24,91	4,5	12,5
4.	Greece	3,94	8,6	20,1
5.	Spain	37,15	19,9	29,4
6.	France	66,00	15,0	21,0
7.	Ireland	0,84	3,6	13,2
8.	Italy	46,46	16,0	25,0
9.	Luxemburg	0,14	2,1	5,7
10.	Holland	3,45	3,5	9,0
11.	Ostrich	39,05	70,0	78,1
12.	Portugal	14,30	38,5	39,0
13.	Finland	19,03	24,7	31,5
14.	Suede	72,03	49,1	60,0
15.	UK	7,04	1,7	10,0
16.	**European Union**	338.41	13.9	22.0

Referring at investments which will be realised in Romania for promoting the utilisation of the Renewable Resources for time period 2003-2010 as first step and the second step 2011-2013 it may be observed a permanent tendency of development every type of resources. In Table 2 are presented the actual

investment (or in trend to be finalised) but also future developments. The word significations: NI-New Investments, TI-Total Investments, NC-New Capacities

Table 2

Utilisation of RR in Romania

Renewable Resources	2003 - 2010		2011 - 2015	
	NI	TI - 10^6Euro	NC	TI - 10^6Euro
Solar -Thermal [10^3 tep]	7,34	75,0	16,0	93,0
Solar–Electric [MW]	1,5	7,5	9,5	48,0
Wind [MW]	120,0	120,0	280,0	280,0
Hydro ≤ 10MW	120,0	150,0	120,0	120,0
Biomass-Thermal [MW]	3249,8	240,0	3487,8	200,0
Biomass-Electric [MW]	190,0	280,0	379,5	400,0
Geothermal [10^3 tep]	17,5	15,0	23,9	12,0
Total	431,5	887,5	789,0	1153,0

2. Analysis of the zone opportunities

The produced photovoltaic energy directly depends of hours spend by solar cells on direct sunshine, geographical position, seasons and daily hour. The maximum produced energy is at noon, with clear sky. For Romania as maximum registered value is considered approximately 1000 W/m^2 (value considered as reference). That means that for a surface of 20 m^2 we may obtain a daily produced energy of approximately 2.8 kVv, respective 5-8 kWh.

First was analysed the area conditions where the pilot station should be implemented, in accordance with the published data, reported by the National Institute of Hydrology and Meteorology, Figure 1.

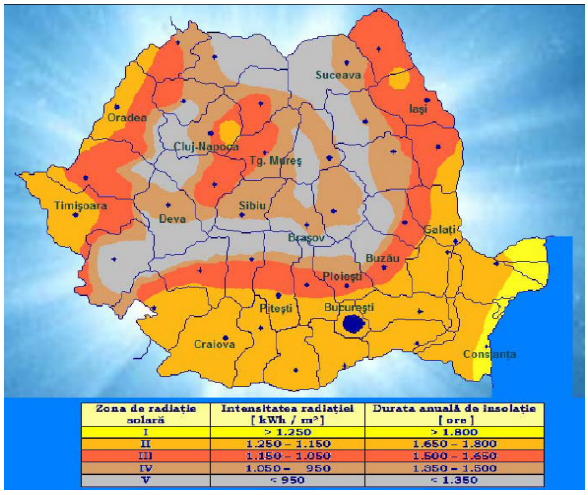

Fig. 1. The Map of solar radiation intensity for Romania

The low efficiency and the total costs, high enough of the solar cells determines the exploitation of such resources in such a way as to utilise the maximum amount of possible solar radiation, higher efficiency of each cells. There are three types of photovoltaic systems: independent, hybrid and connected to the electric system. This Pilot Station realised and implemented during 2008 is directly connected to the electric system. Such a system may assure the local necessary electric energy and the amount of produced energy in excess are delivered into national system. This transfer eliminates the necessity of acquisition and entertainment of accumulation batteries.

This type of system assumed an inverter of high power which may be connected at many panels of solar cells. The electric continue current is transformed into alternative one, synchronized with the system. This one acts as batteries of accumulators without limit of capacity.

In conformity of World Atlas and compared with others area from world we may estimate, that in Romania, there is an important solar potential with a medium density of solar daily incident radiation on horizontal plane as medium value of 3kWh/m^2 x day. There are mentioned 5 zones (0-IV) depending the values of energetic possibilities; more then a half of Romania surface has an important flux of medium energy capable of been produced, between 1100-1300 kWh/m^2 x year

To estimate the opportunity of implementation of the pilot station into the selected area, first were monitored the environmental data, during more then a year; was used an independent station, alimented itself by solar power, equipped with a system of on-line registration and with three weeks data storage.

After that was analysed the principal offers from the photovoltaic market, taking into account that the first 12 producers for cells and photovoltaic modules assure (for year 2007) more then 80% of the whole production. During time were analysed the offers from: Sharp, Q-Cells, Kyocera, Sanyo, Mitsubishi, Schott Solar, BP Solar, Suntech, Motech, Shell Solar, Isofotón and Deutsche Cell. It must be mentioned that today more then 45% of the total production is represented by the Japanese market, Europe 23%, Chine 17% and the rest by small firms, around 15%.

Knowing the selected firms was made a project first for a Photovoltaic Pilot Station and finally for the Photovoltaic Power-plant, the final investment.

3. The design of the Pilot Station system

Further are presented some details from the project of photovoltaic Pilot Station, power 17.4 kW and for the final investment of 40kW. The estimation starting data was determined by introducing the data-base of the realised measurements, made during a whole year, into the same place of further emplacement. In Fig. 2 is presented the schematic type of the Pilot Station (PS).

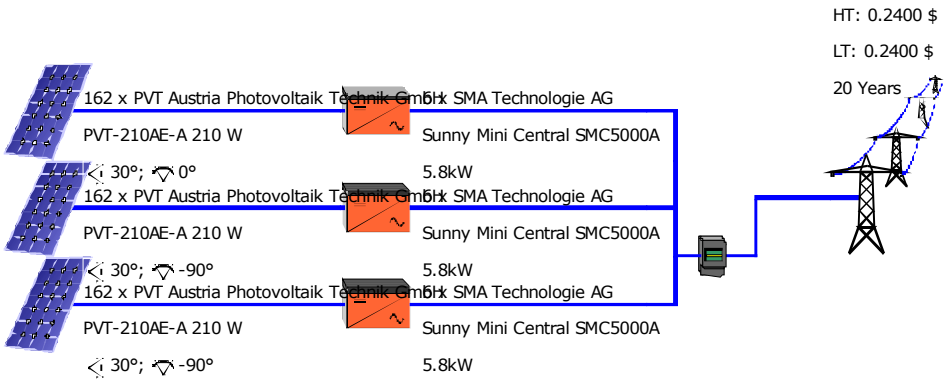

Fig. 2. Schematic realisation of the Pilot Station, power 17.4 kW

For both variants of the PS (17.4 kWp and 40kWp) first was selected the orientation of photovoltaic panels taking account of latitude, longitude of the geographic position of PS and the optimum number of rows. Considering the obtained results and the necessary surface was established 3 rows of panels.

Table 3

Some data from project of PS

Location:	**Judetul Buzau**	
Climate Data Record:	BUZAU	
PV Output:	17.4	kWp
Gross/Active Solar PV Surface Area:	73.14 / 72.47	m²
PV Array Irradiation:	980,171	kWh
Energy Produced by PV Array (AC):	105,716	kWh
Grid Feed-in:	105,716	kWh
System Efficiency:	10.8	%
Performance Ratio:	77.1	%
Specific Annual Yield:	1,042	kWh/kWp
CO2 Emissions Avoided:	93,489	kg/a

Further is mentioned a part of the project for the final investment, at 41KW, into the same position. The results are calculated using a professional mathematical model. There were analysed many solutions of realisation of the PS. First was tested if the photovoltaic are all placed at constant angle, at 30^o, 35^o, 40^o or 45^o. The second variant was to realise the PS in stairs (rows), each one at different angle. There were tested two solutions: of realisation 30^o-35^o-40^o and 35^o-40^o-45^o. These angles are considered as to be an optimum for Romania, area Buzau. Was selected solution in stairs (rows) at different angles 30^o, 35^o and 40^o.

In Fig. 3 is presented the cash balance to estimate the efficiency of the system.

Table 4

Some data from project of final Station 41 kW

Location:	BUZAU		
PV Output:	41.07 kWp		
Gross/Active Solar PV Surface Area:	298.70 / 298.89 m²		
System Efficieny:	10.7 %		
Performance Ratio:	77.8 %		
Inverter Efficiency:	92.7 %		
PV Array Efficiency:	11.5 %		
Specific Annual Yield:	1,188kWh/kWp		
CO2 Emissions Avoided:	43,226 kg/a		
System in Grid Connected Operation			
PV Module	228 x	Deviation from AM 1.5:	1.0 %
Manufacturer:	Cnergy AG	Deviation from Manuf.	2.0 %
Type:	C 180M	Diodes:	0.5 %
Power Rating:	180 W	Due to Pollution:	0.0 %
Power Rating Deviation	0 %	**Inverter**	12 x
Efficiency (STC):	13.7 %	Manufacturer:	SMA Tech AG
No. Modules in Series:	19	Type:	Sunny Boy SB 3300TL
MPP Voltage (STC):	450 V	Output:	3.13 kW
Orientation:	0.0 °	European Efficiency:	94.5 %
Inclination:	35.0 °	No. of MPP Trackers:	1
Mount:	With Ventil.	MPP Tracking:	125 V To: 750 V
Individual Appliances Total Consumption: 0 kWh			
Individual Appliance 1		Type: User-Independent Appl.	0 kWh
Simulation Results for Total System:			
Irradiation onto Horizontal:	395,921 kWh	Own Use:	155.3 kWh
PV Array Irradiation:	456,446 kWh	Energy Produced by PV Array:	52,643 kWh
Irradiation minus Reflection:	436,636 kWh	System Efficiency:	10.7 %
Energy from Inverter (AC):	48,960 kWh	Performance Ratio:	77.8 %
Consumption Requirement:	0 kWh	Final Yield:	3.3 h/d
Energy from Grid:	155 kWh	Specific Annual Yield:	1,188 kWh/kWp
Array Efficiency:	11.5 %		

Economic Efficiency Calculation BASIC PARAMETERS	
Electricity Feed-in: - Grid Concept: Full Supply to Grid	
For the First 20 Years:	0.5112 $/kWh
After:	0.0800 $/kWh
Assessment Period	20 Years
Interest on Capital	3.00 %
Balance of Costs	184803.12 $
Investment Costs	1293.62 $/year
Operating Costs	-
Feed-in Payment Received in First Year	25028.62 $/year
Results According to Capital Value Method	
Capital Value	**196,966.92 $**

Amortization Period	9.0 Years
Net Yield	11.4 %
Electricity Production Costs	0.27 $/kWh

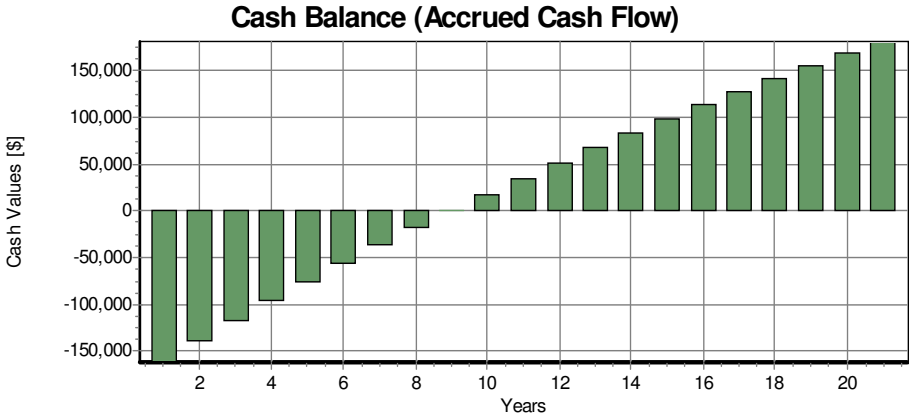

Fig. 3. Cash balance during 20 years for the final investment

4. Implementation of the Pilot Station

To implement the PS was selected an area near Buzau. Next in Fig.4 are presented two pictures made during installation: a- intermediary step and b- a complete panel with 8 PV.

Fig. 4. Images during realisation

5. Experimental results

Next are mentioned the obtained results of monitoring separately two panels delivering electric energy to national system, Table 5. Starting from November 2008 the Pilot Station is continuously functioning. Starting then are recorded the obtained achieving results and an on-line database is realized. At

each set of presented measurement are mentioned the day of recording and the status of sky. Tension without load measured at panel terminals U-P1 = 61,15 V; U-P2 = 64,70 V; the intensity (same conditions) is I-P1 = 1,336 A; I-P2 = 1,304 A

Table 5

Experimental data

Date 12.10.08 Covered sky

Hour	Rad. (W/m^2)	U (V)	I (A)
8,00	7	12,46	0,00
9,00	28	12,48	0,00
9,45	92	12,51	0,25
10,00	131	12,55	0,31
10,40	226	12,68	0,53
11,00	235	13,08	0,53
12,00	202	13,19	0,50

Date 15.10.08 Clear sky

Hour	Rad. (W/m^2)	U (V)	I (A)
8,00	77	12,48	0,00
9,00	419	12,72	0,74
9,20	526	12,91	0,99
10,00	651	13,34	1,24
10,30	735	13,58	1,42
11,00	847	13,64	1,64
12,10	939	13,71	1,80
13,00	932	13,71	1,80
14,00	871	13,69	1,70
14,30	809	13,69	1,61
15.00	710	13,64	1,46

6. Conclusions

Into this paper is presented the realisation and implementation of a Photovoltaic Pilot Station, producing electric energy delivered into national system. First and second paragraphs are dedicated to argument the selected area conditions, type of solar cells, etc. After that are mentioned the numerical modelling, the working hypothesis and the final version adopted. Also are mentioned further possible developments. Finally are presented some experimental data.

In present the pilot station is continue monitored. An on-line data base of meteorological data is collected for the mentioned area. After the pilot station before connection to the national system, there is placed a system of counting the produced energy, to establish the economically efficiency.

After an entire year of monitoring an official recognised data base will be reported to International Scientific Committee of Utilisation of Renewable Resources (SCRRU).

R E F E R E N C E S

[1]. *F. Carlea*, Adviser Ministry of Industry and Resources, "Renewable energy between the European Directive 77/2001 and reality", May Bucharest 2005.

[2]. *Victorita Radulescu,* "The research Centre of high-technology concerning Complex Utilisation of Renewable resources, CITSEA, Contract CEEX 318, 2006-2008.

[3]. *Victorita Radulescu,* Applied Numerical modelling, Editura Bren, ISBN-648-279-05, Bucharest, 2007.
[4]. *Victorita Radulescu, Z. Zetenyi, Alexandra Radulescu*, Complex monitoring of environmental data, International Conference Hydro & Renewable, Lyon, France, 2009.