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Integrated irrigation system with photovoltaic panels and wind turbine

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Abstract. The issue of global food security is amplified by the rapid increase of the population, the climate change that is manifested by the increase of the severity and the variability of the climate. The only safe means of protecting agricultural plants is irrigation. In the paper are presented two systems of microspray and drip irrigation integrated with photovoltaic panels and wind turbine which ensure the irrigation and plant nutrition processes in an autonomous way. The systems have been implemented in two agricultural enterprises to irrigate a good orchard sector.

Keywords: microsprinkler, photovoltaic installation, solar radiation, solar pump, wind turbine.

1. Introduction

Global food security is enhanced by rapid population growth and therefore demand. As a result, world market prices for food increase. Climate change is manifested by increased severity and climate variability. Only an optimal combination of energy and water resources for irrigation, mineral fertilizers and organic soil credit worthiness the Republic of Moldova will ensure continued growth in agricultural production, food security, ensure manufacturing feedstock.
Considering the above, the Government of RM adopted Decision no. 256 of 17 April 2001 „*On the rehabilitation of irrigation systems*". According to the decision is expected to achieve the following: rehabilitation of large irrigation in an area of 124 300 ha which is about 40% of the irrigable area of 1991 irrigation systems will be equipped with mobile irrigation equipment with high productivity low energy and water; an area of 36,000 ha will perform small irrigation; small irrigation is

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expected to be made on land with an area of 1 ha to 100 ha.

The wider objective is creating systems for drip or sprinkler irrigation integrated with energy conversion systems (wind and solar photovoltaic) and computerized intelligent and interactive control by managing simultaneously irrigation, fertilization and phytosanitary treatments application processes.

Basic issues that will be solved are: the argumentation of energy needs of an irrigation system during the growing season; calculation necessary parameters of wind and solar energy conversion systems; development of drip or sprinklers irrigation systems integrated with wind turbines, small hydro and photovoltaic installations; development of an automated interactive system for monitorization and optimization of the water, nutrients and pesticides flow control, that is a useful tool that allows small and medium farmers to set up and master the irrigation, fertilization and plant protection product applications. The transition to renewable energy sources (wind, solar) will reduce the need to import fossil fuels sentient.

The work is characterized by two innovative technical solutions: the first one allows the exploitation of the irrigation system in the absence of electricity networks, the system being powered by converted renewable energy; the second one - the agro-technical parameters of the agricultural land are continuously controlled by a multifunctional sensor block, and the irrigation process itself is managed remotely via ultra-modern communication technologies.

This work, as content, approach and socio-economic importance, can serve as an instructive-teaching example for the teaching and scientific staff of the Technical University of Moldova in achieving a defined goal by solving specific interdisciplinary objectives.

The issue of global food security is amplified by the rapid growth of the number of population and, consequently, by the increased demand for food. As a result, food prices on the world market are rising. Climate change is manifested by the amplification of climate severity and variability. This phenomenon is not a regional one, but a global one (fig. 1).

It is obvious that the sustainable development of agriculture in the Republic of Moldova is indispensable for irrigation and fertilization of agricultural lands. Only an optimal combination of water and energy resources for irrigation, mineral and organic fertilizers with Moldovan soils will guarantee a continuous increase of agricultural production, food security, and will provide the processing industry with raw materials. It will also contribute to reducing soil degradation and the dependence of agricultural production on climate conditions.

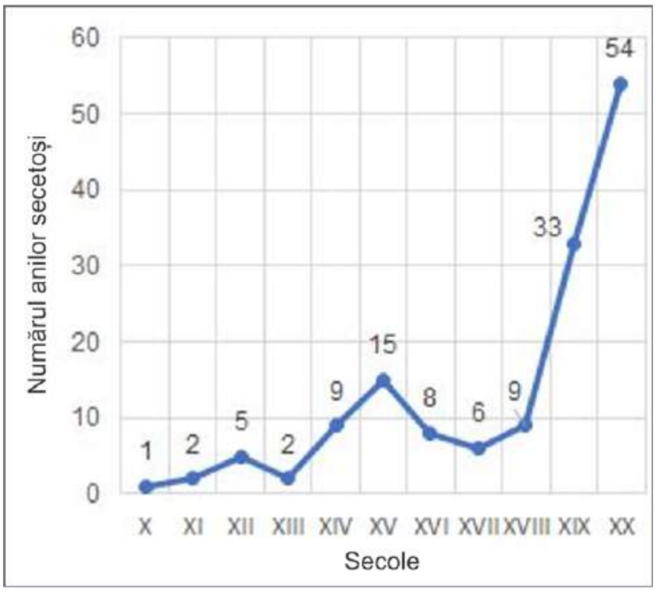


Fig. 1. Number of dry years during the second millennium.

In the climatic conditions of the Republic of Moldova, the optimal water requirement during the active vegetation period is an amount between 300 and 700 mm for most agricultural crops. According to long-term meteorological data for the same period, the average sum of atmospheric precipitations is 235 mm in the southern region and 330 mm in the northern region. Natural moisture is insufficient to obtain the expected production, especially of vegetables, even in the years with average climatological characteristics. The territories of the Republic of Moldova, Romania and Ukraine are often subjected to long drought periods. The only safe means of protecting agricultural plants is **irrigation**.

This was done during the Soviet period, so that irrigated areas reached 291 000 ha in 1990. During 1990-2012, the irrigated areas drastically reduced [1] (fig. 2).

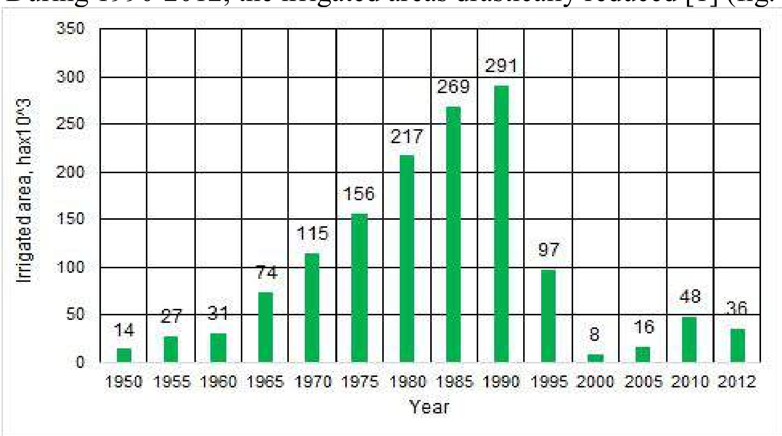


Fig. 2. Dynamics of irrigated surfaces in the period 1950-2012.

After 1991, there were essential reforms in the agrarian sector, characterized first by the restructuring of large agricultural units, decentralization of agricultural production, privatization of agricultural land, formation of new economic relations, based on the laws of the market economy. The increase in the price of electricity and fuel has caused the price increase of one cubic meter of pumped water, which has led to a drastic decrease in the demand for irrigation water from the new agricultural producers. The share of electricity cost often exceeded 50% of total irrigation costs. After 1994 there was a decrease of about 16 times of the irrigated areas and a sudden increase of the share of energy cost in the total cost. In order to redress the situation, the Development Strategy for Agriculture was elaborated in Moldova, which provides for a series of priorities and measures to achieve the proposed objective and to analyze the agrifood sector.

2. Renewable energy sources usable in irrigation systems

The transition to renewable energy sources (wind, solar) will reduce the need to import fossil fuels sentient. The engineering body, economic agents and decision-makers in the Republic of Moldova should be aware of the following truths:

- the Republic of Moldova has a „*renewable fuel*" - the wind from which electricity can be produced on a small and large-scale [2,3];
- micro-hydro and photovoltaic electricity can be produced at low power (tens and hundreds of kW) and will have impact only locally [2,3].

2.1. Wind energy potential and its use

The Republic of Moldova is in the early stages of wind energy development, but in the coming years we will see a rapid implementation of technology for large-scale electricity generation as well as for pumping water for irrigation, heating, power supply of isolated consumers.

In the southern part of the Republic of Moldova there are areas where the average annual wind speeds exceed 4.5-5 m / s at 10 m heights, considered - at the current level of technology development - as prospective areas for the development of wind power (fig. 3).

For the analysis of the wind potential the wind climatology was studied in the outskirts of Floreni village, Ungheni district using the Wind Atlas Analyses and Application Programme [4,5]. In figures 4, 5 are presented wind potential maps.

The analysis of wind climatology in the outskirts of Floreni locality, Ungheni district shows that during the irrigation period (May - September) average daily wind speeds are equal to 3,81-4,24 m/s. And average annual wind power density do not exceeds 150 W/m^2. At the same time, the rated speed of the turbine is 11,0 m/s and average annual wind power density must be greater than 400 W/m^2. Under these conditions, electricity production will be very low, especially in July.

Fig. 3. Estimated wind energy potential map of the Republic of Moldova.

The graphical representation of real energy production (theoretical minus losses, which represents about 15 %) by 10 kW wind turbine are presented in Figure 6. The average capacity of the turbine (see last row) during irrigation is equal to 0,075 or 7,5 %. In other words, only 7,5 % of the 10 kW turbine capacity will be used, or an average only 0,75 kW will be generated, and it is not enough to supply the pump. The average daily electricity output produced by the wind turbine is 18,4 kWh/day and is 2,8 times lower than the output of a photovoltaic panel of the same capacity. The most critical month is July, which is the hottest. The output is 14 kWh/day or 3,7 times smaller than a photovoltaic panel of the same capacity [6].

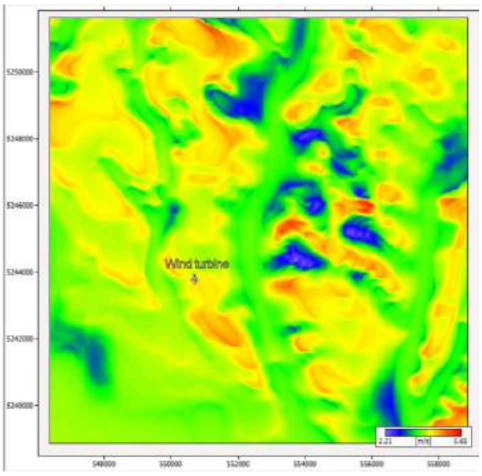


Fig. 4. Average annual wind speed.

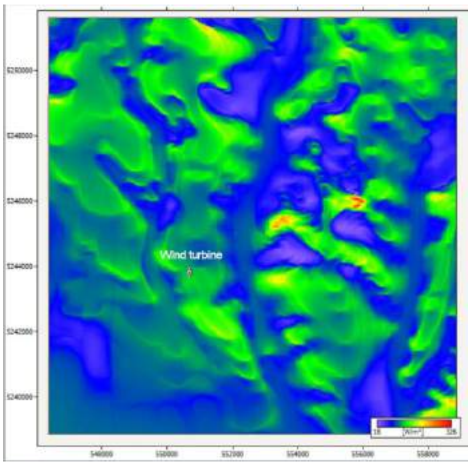


Fig. 5. Average annual wind power density.

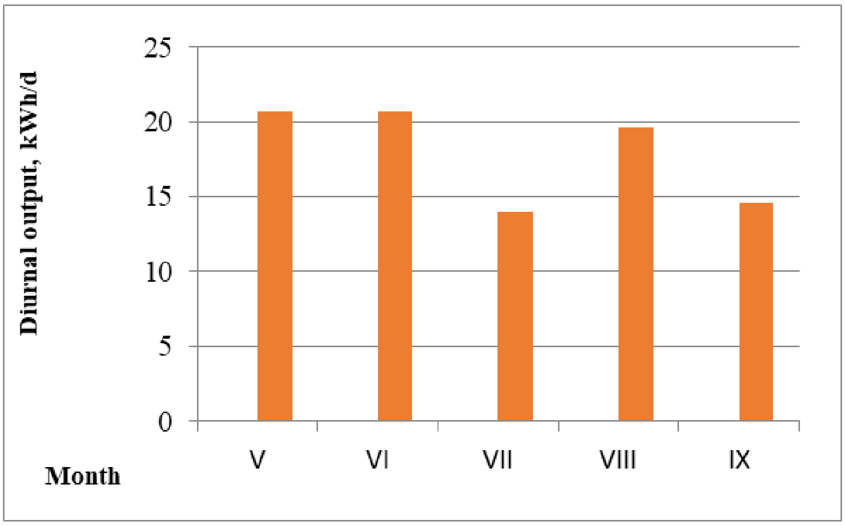


Fig. 6. Average diurnal output for irrigation period.

Concussion: in the warmer period of the year when water consumption for irrigation increases, the wind turbine does not provide the necessary power for pumping and it is not rational to use it in this site.

At the request of the agricultural partners, it was decided to increase the power of the photovoltaic panel by about two times or up to 11 kW for each partner, respectively increasing the costs, which will be covered by the economies related to the installation of the wind turbine.

2.2. Solar energy potential

The amount of solar energy received by the Earth's surface depends on a number of factors, primarily the duration of the Sun's sunshine and the Sun's height above the horizon. In the Republic of Moldova, the possible (theoretical) sunshine duration is 4445-4452 h/year. Actual time is 47-52% or 2100-2300 hours of the possible one. The variation of about 5% is due to the difference in latitude between the northern and southern areas, which is about 2,50. A considerable part of the sunshine hours are in the months from April to September and is about 1500-1650 hours. The global radiation (sum of the direct and diffuse radiation) on a horizontal surface, under medium nebulous conditions, is 1280 kWh/m^2/year in the northern area and 1370 kWh/m^2/year in the southern area (fig. 7). More than 75% of this radiation lasts from April to September. Global radiation in the northern area is 3,5% lower than in the central area, and in the southern area – 2,6% higher.

Fig. 7. Solar energy potential map of the Republic of Moldova.

The irradiation values present the results of the systematic measurements carried out by the State *Hydro meteorological Service* between 1954 and 1980, in conditions of clear sky and medium nebulosity, at 6^{30}, 9^{30}, 12^{30}, 15^{30} and 18^{30}. With this data irradiation (exposure) can be defined over a concrete duration in kWh/m^2 or MJ/m^2, taking the irradiation integral over that time interval. Using this software [7], we calculated the diurnal radiation at Chisinau meteorological station on horizontal surface. The results are included in Table 1.

Table 1. Month needs of energy.

Luna	E_d, kWh	E_l, kWh	E_{dmed}, kWh	E_{lmed}, kWh
I	5.6	174		
II	9.5	266		
III	16.7	519		
IV	20.1	604		
V	23.5	729		
VI	23.7	711	15.7	478 anual
VII	23.9	740		
VIII	22.4	694		
IX	17.6	527		
X	13.3	413		
XI	7.3	218		
XII	4.7	146		

We note the following:

- The average error from April to September in the period 9^{30} - 15^{30} does not exceed + 3,0%;
- Early in the morning (6^{30}) and evening (18^{30}) the errors are high and may exceed 100 %. But this does not affect the calculations because at the respective hours the PV pump does not work.

The fig. 8 show hourly radiation (on left) and pump flow (on right) on July month.

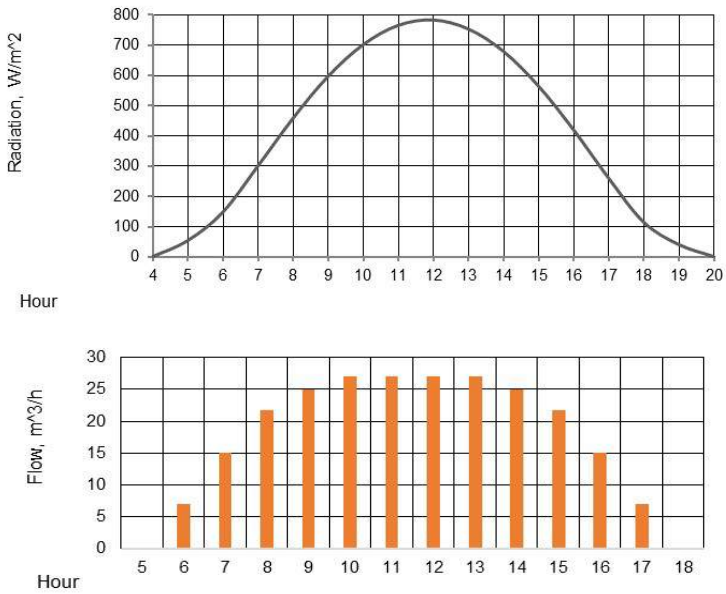


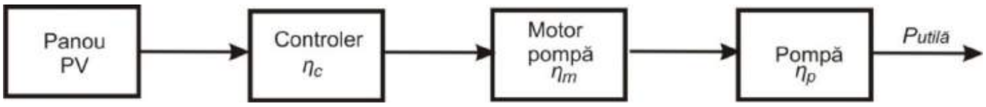
Fig. 8. Hourly radiation (on left) and pump flow (on right).

3. Sprinkler autonomous irrigation systems development integrated with renewable energies conversion equipment

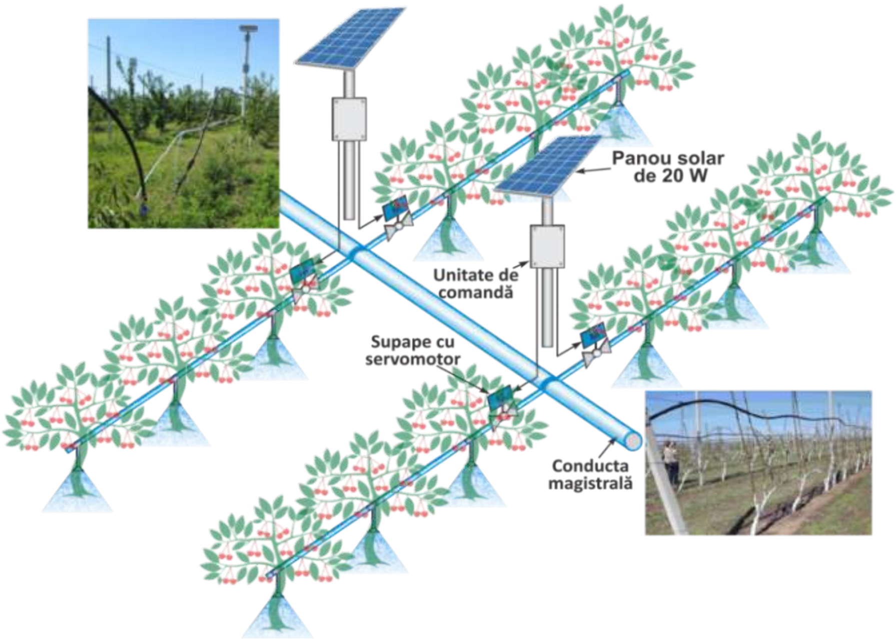
The development of sprinkler autonomous irrigation system has been planned. It was necessary to develop a hybrid conversion equipment with 10 kW wind turbine and PV subsystem. In order to make the final decision regarding these two equipment, the wind and solar energy potential were analyzed in the respective sites. To reduce costs, it was decided not to use battery packs. In this case irrigation will occur if the values of the solar radiation or the wind speed exceeds the minimum values necessary for the operation of the pump.

The functional, conceptual and technological schemes are shown in fig. 9,a,b,c. The following is a case study for an irrigation plot [6].

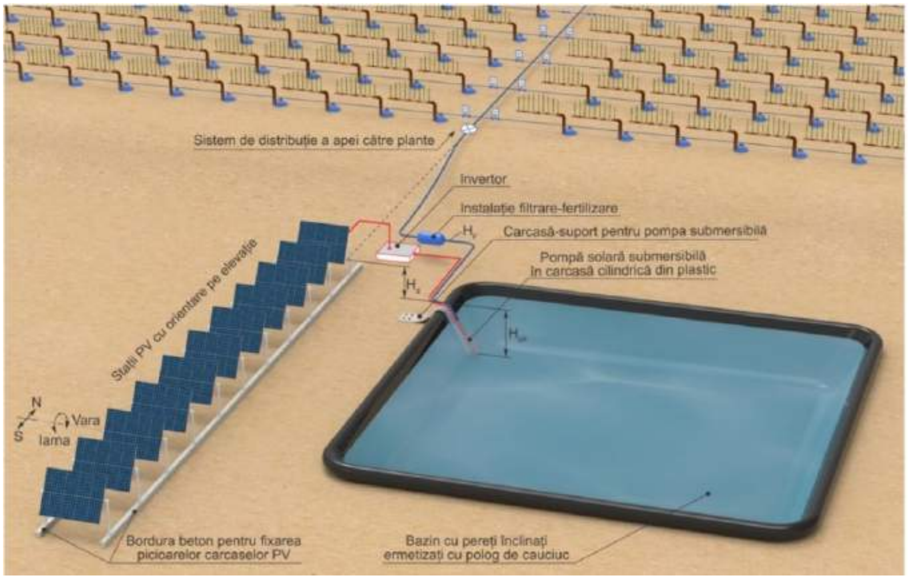
- Irrigated surface, S=7,0 ha or 2 land plots of 3,5 ha of cherry orchard comprising 22 rows. Is located 10 km away from the Dniester River, with coordinates: wide. 47°12'04,00 N"; longitude 29°07'36,33" E.



a. The functional scheme.



b. The conceptual scheme.



c. The technological scheme.

Fig. 5. The technological scheme of the autonomous irrigation system.

The land has no obvious inclinations, the altitude of the 4 corners: 97, 99, 105,103 m. A water tank is built for the storage of 9000 m^3 of water, being pumped from the Nistru River.

- Irrigation technology - Micro Sprinkler. Micro Sprinkler Type - SuperNet UD. Pressure and water flow of a Sprinkler: P_{SPmax} = 4,0 Bar and Q_{SPmax} = 0,058 m^3/h, P_{SPmin} = 1,5 Bar and Q_{SPmin} = 0,03 m^3/h.
- Period of irrigation season: April – September or T=183 days.
- The number of operating pump hours in the event that the number of operating hours per day is equal to N_{day} = 7 h, $N_h = N_{day} . T = 7 \cdot 183 = 1281\ h$.
- The total dynamic head: $H=45\ m$.
- Irrigation norme, N_I = 5000 m^3/ha.
- Watering rate, N_U = 300 m^3/ha.
- Length of row in a sector, A= 170 m.
- Watering rates per season, $NR_{UD}=N_I\ /\ N_U$ =5000/300=16,7, accepting N_U =16.
- Width of sector, B=99 m.
- Row width, L_R = 4,5 m.

Necessary water volume: $V_{nec.}=S \cdot N_I$ = 7·5000 = 35000 m^3.

4. Conclusions

Concussion: in the warmer period of the year when water consumption for irrigation increases, the wind turbine does not provide the necessary power for pumping and it is not rational to use it in this site.

At the request of the agricultural partner, it was decided to increase the power of the photovoltaic panel by about two times or up to 11 kW.

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