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Energy Savings Automated System for Complex Irrigation

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Abstract: The paper presents the ways of energy savings in agriculture in a project for irrigation of small and medium vegetable farms (2 ha or less, which dominates the vegetables market in Romania), in the attempt to increase their profitability. The savings were not viewed directly justas consumption from the mains, or other fossil fuels energy, but also indirectly, as inputs reduction (water, nutrients, pesticides), since their capture, extraction, transportation, production and distribution involve energy consumption too. One way of our approach was saving water and apply fertilisers and pesticides responsibly - manage irrigation and fertilization together to optimize efficiency. The application is based on an intelligent and interractive computer based controlled system for effective irrigation/fertigation and chemigation scheduling. The wetting method was mainly by drip irrigation, well known for its high water application efficiency and minimized losses of fertilizers and nutrients, combined with sprinkler irrigation. The software was conceived as a practical and efficient tool to calculate (based on informations which determine the crop's needs) the irrigation and fertilisation needs for vegetables using drip/sprinkle irrigation, under set conditions described by the user. Another way to minimize energy was the designing of electronic parts at lowest energy consumption possible. In the paper it is particularized the block of sensors which electric diagram was built around an ultra-low power mixed signal microcontroller that allowed the use of a photovoltaic cell together with an accumulator to supply the voltage.
Key words: Wireless sensors network, photovoltaic cell, irrigation controller, drip irrigation.

INTRODUCTION

Small farmers have their own place in agriculture, because what they are capable of producing can be different from what a large farm can produce, but their efficiency should be improved to allow penetration of market niches. In vegetable production, efficiency means stopping wastage of water, energy savings and an intelligent methodology for nutrient and pest control, all this with a minimum labor and a higher yield.These goals can be obtained these days only by automation of the irrigation-process based on vegetable needs quantized through specific sensors. Engaging electronics requires compliance with European directives and regulations regarding the restriction of dangereoussubstances for environment (RoHS 2, REACH) and the waste management of electrical and electronic equipment (WEEE) [*Directive 2011/65/EU,2011; Regulation (EC) No 1907, 2006; Directive 2012/19/EU, 2012; Directive 2002/95/EC, 2003; Directive 2002/96/EC, 2003*]. On the other hand, various electronic modules of the automation system are designed to work on summer in full sun, at the ground level, where temperatures of 70ºC are possible. Therefore, the designer has to consider the consequences of the higher operation temperature over the components and their solder joints in order to chose the proper materials and process for assembling (*Plotog et al., 2013; Plotog, Marin and Boanta, 2013; Svasta and Plotog, 2010; Branzei et al., 2013*).

Tests were conducted in the laboratory to provethe concept and will be followed by experiments in real condition in the land.

MATERIALS and METHOD

The proposed Energy savings automated system for complex irrigation whose principle diagram is shown in figure 1 presents as feedbackloop a wireless sensors network (WSN). The energy can be saved both by hardware and software design of the WSN. In order to minimize the power consumption of each node of the WSN, multiple soil and environment parameters are monitorizored by specific sensors controlled by a single very low-power microcontroller.

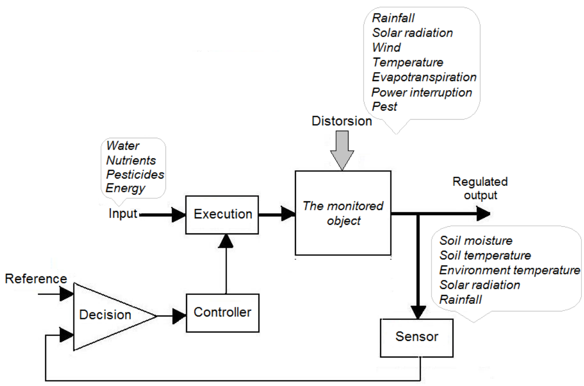

Figure 1. The principle of an automated irrigation system

The parameters taken into consideration were the soil moisture and temperature, the environment temperature, the rain water and the solar light. From the various offer on the market it was chosen a mixed signal microcontroller, MSP430F2274, from Texas Instruments, which active/standby modes power consumption are 270 μA/0.7 μA at 1 MHz, 2.2 V (http://www.ti.com/lit/ds/symlink/msp430f2274-ep.pdf).It also controls the wireless communication through the low-power 2.4 GHz RF Transceiver, CC2500, from the same manufacturer (http://www.ti.com/lit/ds/symlink/cc2500.pdf). Thus a single power supply is needed for the electronics of each node. The natural solution is the solar energy, but it has to be sustained by a secondary energy storage device–a rechargeable battery. Also, a single battery of 1.2 V/2700 mAh was chosen. They are the primary voltage for a DC-DC converter which ofers the higher necessary voltage for the electronics (3.3 V). The solar module (Figure 2) was selected in order to offer enough energy to deliver to the storage device and to the converter. According to the datasheet, it offers 407 mW, 2.2 V at Standard Test Conditions, STC (1000 W/m2 sunlight AM1,5, cell temperature 25°C) (Q-mo solar AG, Solar Module SMH 4-0380, Technical Document, Rev.7/2011).The role of the solar module is to charge the battery, since the main activity of the irrigation system is performed when the sun is not shining or at all. The maximum power consumption of the circuits from the node are tabulated in Table 1. They are used for dimensioning the converter. Note that these are maximum values of the main circuits given by datasheets, but the real value should be achieved through an increase to cover the consumption in other loads. These are confirmed by measurements. For example, during the transmission of a parameter through the transceiver block a voltage of 30.4 mV was measured across a 1 Ω resistor interposed between it and the source, which gives a 30.4 mA current consumption. However, the duration is less than 5 seconds (Figure 3). A value incresed by 50% seems to be sufficiently cover. As conclusion, it was designed a DC-DC step-up converter with the following requirements:

-İnput voltage: 0.65V...3.3V
-Output voltage: 3.0V...3.6V
-Output current: 100 mA.

The converter was established on the basis of the circuit MCP1640, 0.65 V Start-up Synchronous Boost Regulator with True Output Disconnect or Input/Output Bypass Option, from Microchip Technology. It offers an adjustable output voltage range from 2.0 V to 5.5 V, which covers the needs of the design. As recommended by the manufacturer, the values of the adjusting resistors were calculated for a 3.3 V output voltage.

Further, combining by software the active and low-power modesand including reasonable period of measurements sampling, as well as data transmission moments will be minimizedthe energy usage.

Continuing with this first step of power management, each node of the WSN will be able to collect data from the environment by means of specific sensors and to send them to the Central Control Unit in order to process it and to pass to a higher level of energy savings.

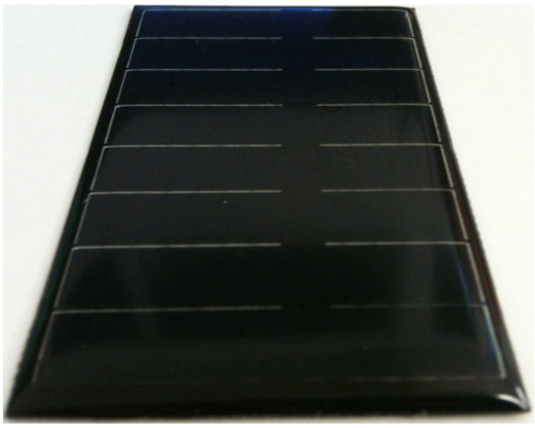

Figure 2. Solar module SMH 4-0380, 67.5 x 41.0 mm

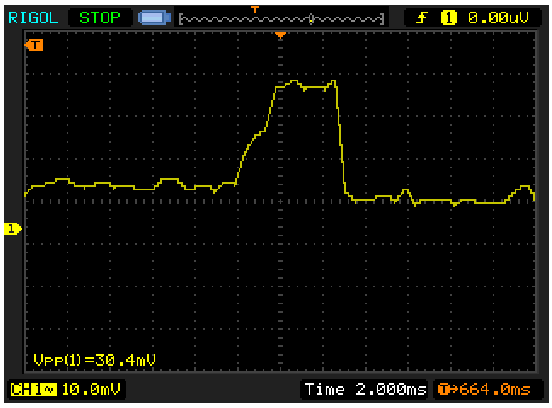

Figure 3. Determination of current consumption during the transmission of a parameter

Table 1. Maximum and minimum power consumption of the circuits from the node

Circuit	Maximum current [mA]	Minimum current [μA]l
CC2500	21.5	0.9
MSP430	3.1	0.7
DS18B20	1.5	5
Soil moisture sensor	5.5	0
Rain sensor	5.5	0
TOTAL	36.6	6.6

In interactive systems for optimizing inputs of water, nutrients and pesticides the central element that controls the entire activityis the irrigation system controller – CSI. It features hardware and software resources necessary to fulfill all the functions of the system.

The proposed irrigation system controller provides:

1. Acquisitionsignals from sensorsthat control the operation of theirrigationsystem (pressure sensors, flow, level);
2. Acquisition signals from sensors measuring soil parameters (moisture, temperature) and environmental parameters (temperature, relative humidity, light intensity, atmospheric pressure);
3. Ordering the execution elements of the system (valves, pumps, dispensers);
4. Implementing algorithms irrigation, nutrient and pesticide management;
5. Operator interface;
6. Connectivity in wireless sensor network and Internet.

Asshownin figure 4, the irrigationsystem controller contains the followingfunctionalblocks: **1**-analog interface block which receives signals from those process transducers and sensors connected through wires (transducers and sensors with unified signal output or differential output), **2**-transmitting commands to the drive, **3**-receiving status signals of the process (signals in frequency or pulse train), **4**-Ethernet interface block that provides connection and communication in an Ethernet network, **5**-processor based on a microcontroller on 32-bit, processing information acquired from the process as a program enrolled in non-volatile memory of the microcontroller, **6**-serial interfaces that can connectdirectly to a computer, a programming console or modem, **7**-real - time clock RTC and serial EEPROM, **8**- programming interface/BDM debugging, **9**-standard communication interface which provides communication in a wireless sensor network.

To acquire signals from pressure sensors, flow, level, which control the operation of the irrigation system, the irrigation system controller – has analog inputs and digital inputs (signaling). Using wired sensors, these sensors must be located as close as possible to the module and are connected via wires to analog inputs or digital, respectively. If the system or farm owner requires wired field sensors (measuring parameters of soil and environment) these should be connected to analog inputs.

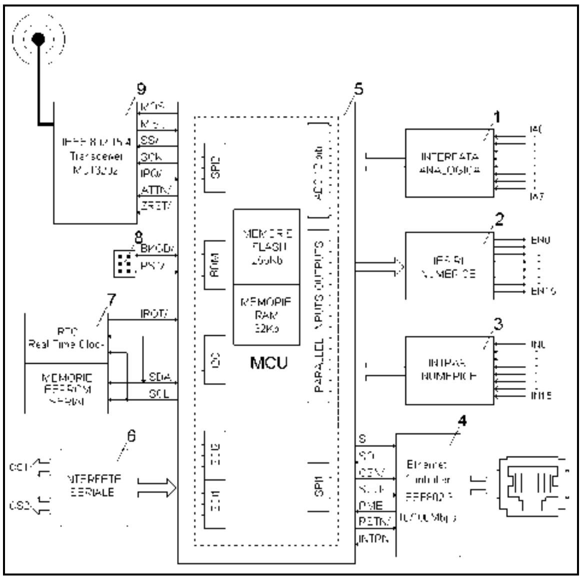

Figure 4. The block diagram of CSI –controller for irrigation system

To avoid the use of wiredsensorsonly,and considering the rapid spread of wireless sensors in agriculture and to meet the requirementsimposedby Precision Agriculture- PA and Variable Rate Technology- VRT, CSI isequipped with ZigBee wireless interface in the 2.4 GHz industrial, scientific and medical (ISM) radio band. Through this interface the controller is connected to WSN (measuring various parameters of the soil and environment), with sensors distribuited randomly or not in the field.

The proposed system of drip irrigation/fertigation/ chemigation, on the side of mechanical-hydraulic components,has been designed keeping in mind the requirements and specific scheme for setting up a specific crop, minimum human intervention and the lowest energy consumption possible. All design is flexible and requires just a few parameters from the owner to set it up.

As a result, the mechanical-hydraulic characteristics of the installation are based on: crop, irrigated surface area, number of rows, number of plants per row (distance between plants in row).

In order to obtain a real energy savings system it had to be chosen the most efficient components: pump (s) - with advanced control and functions, 9 V digital flow meter (s), digital gauges, 9 V irrigation valves (the electromagnetic solenoid economic technology of 9 V for minimum pressure loss in the flow of water has optimized geometry), electro-pressure regulator (s), 9 V hydraulic pressure sensor. Since the pump was the single component using 230 V/50 Hz mains power, a proprietary model was designed to be fed from a 12 V/24 V power supply.

It was chosen the 9 V electrical power supply technology as being the lowest power supply which can assure good functioning of the whole electric and digital components of the system, with few exceptions. Using this technology it could be droped the amount of energy needs to a minimum.

With HDPE pipes, the system can perform several functions as: irrigation, fertigation with N, fertigation with P, fertigation with K, spraying insecticide, fungicide spraying, splashing herbicide.

To inject nutrients into irrigation water two types of venturi head injector were used: one for nitrogen, phosphorus, potassium and the second one for insecticide, fungicide, herbicide.

Energy savings are obtained also by minimizing the losses due to water return or water impurities. In order to prevent the return of water one-way check valve was mounted on every pipe. This valve allows flow in one direction and blocks the other way; mainly it consists of a fixed part connected to a conduit (rigid or flexible) and a mobile element (ball or cone plate) sliding.To protect the pump, solenoid, drip tubes, the sprinklers, etc. Fromimpurities from water disc filters were provided. These filters are manufactured under ISO 9002 standards and UNI ISO 7/1.

The last, but one of the most important element in achieving the goal of energy savings is the software. A resonable fast period of parameters determination, the accuracy of the measurement, the real time data analysis and processing, as well as the proper scheduling of the agricultural works according to the plant needs (growing, maturing, type, a.s.o.) can prevent the waste of water, ingredients, and lastly energy. IT system will lock or unlock any component of the system depending on the information provided by sensors.

RESULTS and DISCUSSION

The use of a solar module of 407mW and a Li-Ion rechargeable battery of 2700mAh capacity in the project, to power wireless multipurpose multichannel sensor, is efficient and assures enough energy in order to remove the use of a third type of storage energy like supercapacitor (*Martino and Varley, 2012*).

Filter pressure reducer reduces the initial pumping pressure to a level of approximately 150 kPa (1.5

bar), for optimal performance of the heads and nozzles connected.

The installation of drip fertigation and spraying with insecticide/fungicide/ herbicide will have to serve small and medium-sized farms.

Water quality, source water is, in many rural areas, is not so high, so it is necesary to be filtered at the entrance in sistem.

In the final phase of the project quantitative analysis will have to be carried out in order tohighlight the degree of reduction of energy, water waste, ingredients compared to other irrigation systems on the market.

CONCLUSIONS

The achievement of the feedback loop of the automated irrigation system as an energy autonomous entity is a viable solution forenergy savings. Therefore the size of the WSN is not limited by the energy-related cost.

The technology of 9 V electrical power supply used in this type of installation proved to be the most efficcient one which could assure good functioning of the whole electric and digital components of the system.

The pressure of energy cost for farmer is lowered to a minimum affordable level.

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