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Autonomous Monitoring System of Environment Conditions

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Introduction

Recently, considerable interest in wireless telecommunications based on technology such as Global Systems for Mobile Communications (GSM) with GPRS/EDGE transmition network commercial is widely available. The wide spectrum of sensing elements and various detectors of a low energy consumption made development of advanced sensory networks for different applications possible [1-6,9,10]. In the paper an autonomous monitoring unit combined with an early warning system (EWS) for on-line control of environment is presented and discussed. The primary element is the sensory network composed of installations of measuring stations distributed over the required monitoring area. It is completed with basic service sets for data acquisition.

Structure of the monitoring system

It was assumed, under designing, that zones being monitored can be distributed over any controlled area. As an example heavy industrial environments as well as areas of national parks that require careful control and protection were selected as it is illustrated in Fig.1.

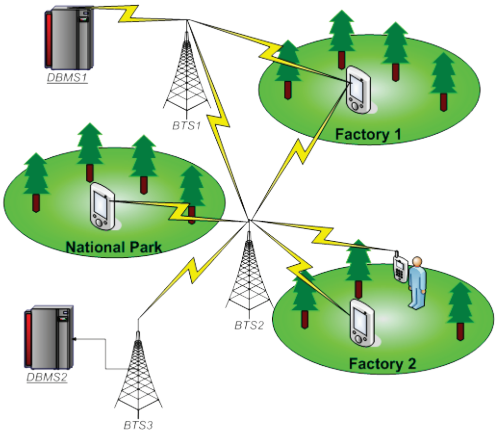

Fig. 1. General architecture of monitoring system

Current data from outputs of employed sensors located over the monitoring space are acquisited by means of respective concentrator equipped with GSM terminal. Therefore, due to direct connection to GSM/GPRS network they are transferred on-line to proper servers indicated as DBMS1-2 in Fig.1.

The main goal of this work was to allow for free arrangement of all measuring stations and for their arbitrary location as well. The GSM is at present commonly applied technology of the wireless telecommunication. Due to prevailing tendency in the world market a flexible access to Internet has become common and cheap. The advanced technology makes the ready-to-serve, high integrated and programmable GSM modems with wide accessible peripheries available (e.g. price of a microcomputer with GSM is today even below 50€). Data infrastructure of operators guarantees the network coverage in 99% of territory for almost each country. Although, WiMAX, WiFi and/or WSN 2.4 GHz can be used as an alternative technology but unfortunately it requires development of a respective network infrastructure. However, after all the WSN technology (due to detection range below 100 m) can be replaceable when use wiring connection between sensor and concentrator.

According to block diagram of a sensor mode for developed monitoring system (see Fig.1.) the each sensor node is composed of GSM/GPRS modem for data transmition, microcomputer, selected sensors and energy provided by battery unit controlled and charged by a solar energy set (see Fig 2).

The embedded CPU is integrated with the GSM modem (called as concentrator) and connection with selected sensors applied. For the pilot study of the monitoring system the following sensors as indicated in Table 1 were selected. The selection was performed taking into account the obligatory standard requirements [7,8]. For simplicity of solution and to reduce the cost as much as possible all sophisticated, high energy-consuming and required specified servicing (like frequent exchange of filters, individual chemical analysis of samples in a lab etc) both sensors and detecting systems were omitted (floating dust and heavy metals – like Pb, As, Ni, Cd – measuring units). By reason of this we were focused on gaseous chemosensors and detecting elements of such basic physical quantities like humidity, temperature and pressure.

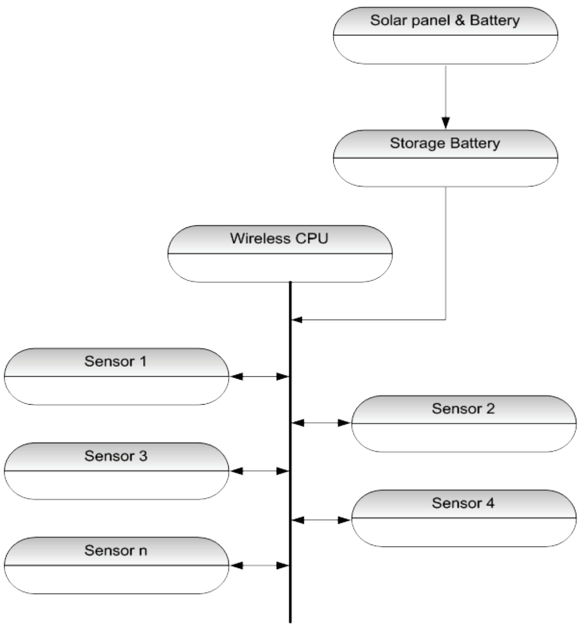

Fig. 2. Block diagram of sensor mode

Table 1. Selected sensor parameters

Measured quantity	Type	Current mode		Acceptable level of emission acc [7, 8]
		active mode [mA]	sleep mode [mA]	
Wireless CPU	Q2687H	350	35	-
Temp&Hum	SHT75	0,03	-	-
Carbon Monoxide (CO)	TGS2442	3,9	-	10000 μg/m^3
Carbon Dioxide (CO_2)	TGS4161	50	-	9000 mg/m^3 per 8h
Air contaminants (Ethanol, Toluene, Hydrogen)	TGS2602	60	-	-
Ammonia (NH_3)	TGS2444	15,5	-	-
Diesel Engine Exhaust Gas (NO, NO_2)	TGS2106	90	-	200 μg/m^3 per hour or 40 μg/m^3 per year
Organic Solvent Vapors (Ethanol, Benzen, Methane)	TGS823	140	-	5 μg/m^3 per year for benzen
Sulfur Dioxide (SO_2)	SO2-AE	0,25	-	350 μg/m^3 per hour or 125 μg/m^3 per day
Atmospheric pressure	MPX5100A	7	-	-

Analysis of energy balance for the monitoring system

One of the basic assumptions was to use an autonomous source to provide electrical energy to the system. We have selected an available photovoltaic battery set of an accepted efficiency that is easy for handling and servicing. The size of the solar panel is strongly related to:

- sensor types predicted for use (power or current consumption),
- frequency as well as measurement duration accepted,
- frequency of a data transmission from concentrator to server.

Before the photovoltaic source was selected the measurements of both temperature and irradiance (power incident on a surface) were performed at the area predicted for the system location. Therefore, both amount of available energy from the solar panel under heavy environmental conditions was able to be estimated as well as information on the temperature influence on the battery capacity could be specified. Luckily the measurements were conducted under the most unfavorable (for the photovoltaic battery set) conditions of operation i.e. during season of a heavy winter of 2009/2010 years. The sun irradiance versus time during 2 months (from 2009-12-13 till 2010-02-11) of measurements is presented in Fig.3.

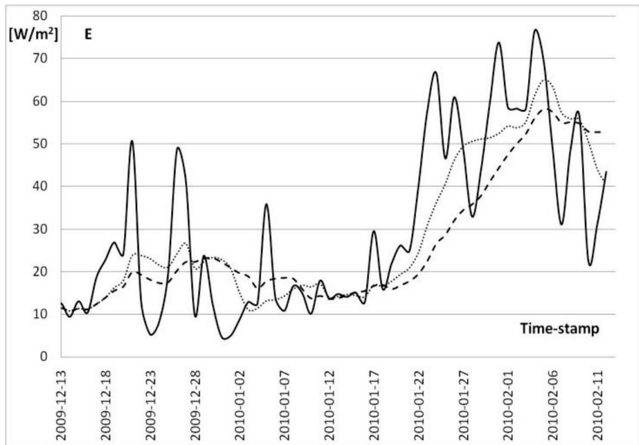

Fig. 3. Sun irradiance E versus time (— mean value for particular day, ···· mean value for one week, --- mean value for two weeks)

The plots E=f(t) represent mean value of particular day (curve —) and rolling means (simple moving average) for 7 days (curve ····) and for 14 days (curve ---) respectively. One can notice a high dynamics of the irradiance value variation related to atmospheric conditions. The most convenient for estimation of the worst case of accessible electrical energy level is found to be the rolling mean for 14-days as illustrated by curve --- in Fig.3. Under the measurements a direct interdependence between level of irradiance (14 days rolling mean) and mean value ambient temperature can be observed as it is shown in Fig.4.

As one can see the local maximum value of the irradiance corresponds to maximum drop (below 0°C) in temperature (it is related to open sky anticyclone conditions). It is obvious that battery capacity and its efficiency are both sensitive to a low ambient temperature value. When analyze the energy balance of the monitoring system one has to know electrical performance of the solar panel applied at specified irradiance level. For example the current-voltage characteristics of KYOCERA solar module at cell temperature equal to 25°C are presented in Fig.5. Therefore, for the heavy winter conditions one has to take into account the decrease of efficiency according to operational temperature of the solar panel (temperature coefficient of maximum power).

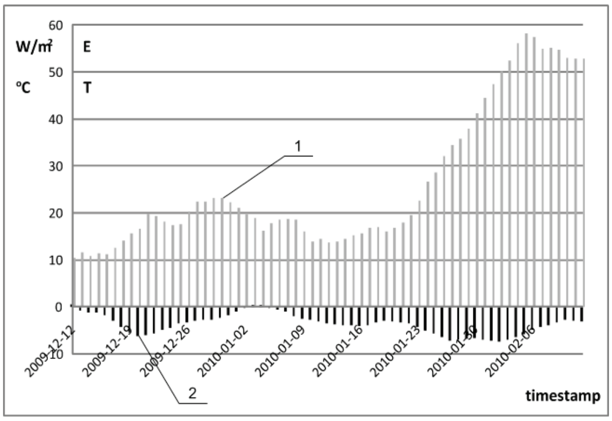

Fig. 4. Relationship between temperature T-(2) versus irradiance E-(1) during winter time

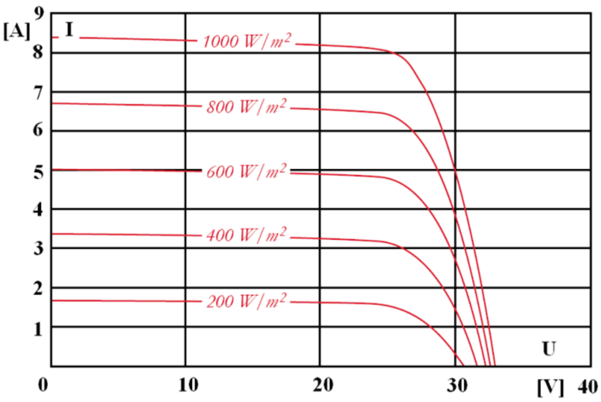

Fig. 5. Current-voltage characteristics at various irradiance level (at 25°C)

For the analyzed period of time the mean value of ambient temperature was around -7.5°C, therefore, the efficiency of the solar panel was decreased by about 16%. While, considering importance of analyzed, measuring quantities their slow variability with time could be assumed. Therefore a sequentional operation of the sensors was able to be taken into account, as it is seen in Fig.6.

As a matter of fact the operational mode was fixed as follows:

- continuous active mode for humidity and temperature measurements,
- sequentional mode for remaining parameters specified in Table 1 i.e. active – 15s and sleep – 345s respectively,
- data transmission: 30s,
- full measuring cycle duration equal to 6 min. (including transmission time),
- 10 measurements per hour.

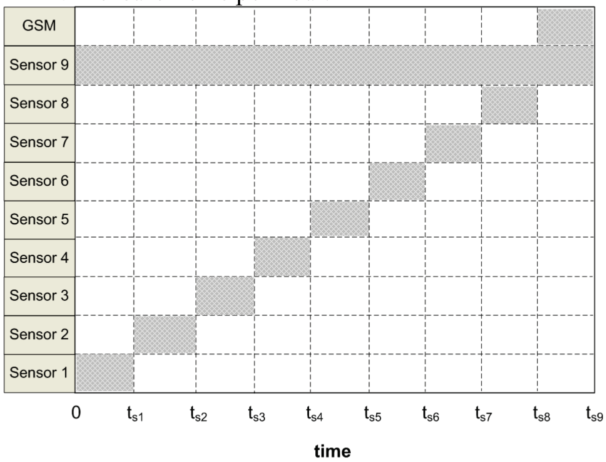

Fig. 6. Illustration of sensors operational scheduling

For the assumed operational mode of the monitoring system when use the sensors listed in Table 1 a mean current consumption (for 1 hour duration) can be estimated from

$$I_{mean} = \left(\sum_n t^A_{S_n} \cdot \left(i_{S_n} + i_{CPU}\right) + \sum_n t^S_{S_n} \cdot i_{CPU} + t_{TRX} \cdot i_{TRX}\right)/\tau, \qquad (1)$$

where t^A_{Sn}, t^S_{Sn} – estimated active and sleep time of s_n-sensor respectively; i_{Sn} , i_{CPU} – current consumed by s_n-sensor and processor respectively; t_{TRX} , i_{TRX} – GSM/ GPRS transmition time and current consumption during transmition.

Therefore, the total one cycle duration τ and current mean value I_{mean} are able to be found as below

$$\tau = \sum_n \left(t^A_{S_n} + t^S_{S_n}\right) + t_{TRX}, \qquad (2)$$

$$I_{mean} = i_{CPU} + \left(\sum_n t^A_{S_n} \cdot i_{S_n} + t_{TRX} \cdot i_{TRX}\right)/\tau. \qquad (3)$$

Due to various rated voltage of the sensors applied the current consumptions was found to be more convenient with compare to the active power level..

As a result the mean current value necessary for reliable operation of the monitoring system must be not lower than 77 mA. At emergency case, if the electric energy has to be provided only from the storage battery within 14 days its minimum capacity should be at least 32 Ah.

Conclusions

The advanced design of the autonomous monitoring system of environment conditions has been developed and involved in practice. It is composed of the embedded CPU unit integrated with the GSM modem and connected to concentrator with selected sensors applied. One of the major problem is to consider carefully an energy balance to fulfill requirements concerning independent sun battery powered autonomous supply. It was found to be obtained by proper selection of the sensor scheduling adapted for real weather conditions.

Acknowledgements

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The contract for refinancing No. POIG.01.03.01-02-002/08-00.

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Paper presents the developed autonomous monitoring unit combined with an early warning system for the on-line control of environment. Problems of the proper selection of the sensors and strategy of data acquisition and processing to reduce the power consumption as much as possible are discussed. Ill. 6, bibl. 10, tabl. 1 (in English; abstracts in English, Russian and Lithuanian).

Б. Миедзински, К. К. Рутэцки, М. Габрих. Автономная система для мониторинга средовых режимов // Электроника и электротехника. – Каунас: Технология, 2010. – № 5(101). – C. 63–66.

Представлена разработанная автономная контрольно – измерительное система, соединенная с системой предупреждения предназначена для мониторинга режимов среды. Рассмотрены проблемы выбора параметров датчиков и стратегия подборки и обработки данных для уменьшения до минимума потребления мощности. Ил. 6, библ. 10, табл. 1 (на английском языке; рефераты на английском, русском и литовском яз.).

B. Miedzinski, K. Rutecki, M. Habrych. Autonominė monitoringo sistema // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2010. – Nr. 5(101). – P. 63–66.

Aprašoma originali kontrolės ir matavimo sistema, tiesiog sujungta su aplinkos stebėjimo sistema. Plačiai išnagrinėti įvairių keitiklių parametrai ir pasiūlyta gautų duomenų analizės strategija. Sistema gerokai sumažina naudojamą galią ir tiksliau atpažįsta pavojaus signalus. Il. 6, bibl. 10, lent. 1 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).