2015 International Siberian Conference on Control and Communications (SIBCON)

Power Supply System for Wireless Sensor Network

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***Abstract* — The autonomic power supply system for wireless sensor network based on renewable energy sources was developed. The main factors affecting its operation during the use of main gas pipelines as a part of detection system gas leak. An adaptive algorithm for the battery charger operation and the transceiver module are proposed. The selecting technique of the preferred source of energy depending on the given region is presented below.**

***Keywords*— wireless sensor network; autonomic power supply system; renewable energy source; battery charging controller; transceiver (receive-transmitting) module.**

I. INTRODUCTION

Urgent problem of monitoring of the technical condition of extended main gas pipelines [6, 7, 9, 11] can be solved by means of the telecommunication technologies. Paper [5] proposes the use of wireless sensor network (WSN) that gives an opportunity to create reliable, multi-level, self-organizing data transmitting systems. Such distributed systems are offered to make using special hardware supporting ZigBee data transmitting standard that permits to cover a large area at relatively low power transceiver equipments.

The main and basic elements of monitoring the telecommunication systems based on WSN are autonomics miniature computing devices equipped with sensors (building deformation sensors, gas leak sensors, sensors of temperature, moisture etc.) so-called motes.

Storage batteries (accumulator) are used as the main power energy source in this system; it enables a long-term operation of autonomic separate motes. But the use of the storage batteries is a well-reasoned solution only in strictly defined temperature range. Leaving this range greatly decreases the capacity and robustness (reliability or time resource) of the battery, which can lead to fast failure of the sensor elements. So, during the creation of WSN for gas leak monitoring [1, 2] it is necessary to enable an additional power supply which is able to keep up system operation at severe environment conditions of Siberia and the Far North with battery charge control.

Proposed autonomic power supply system (Fig. 1) consists of the following elements:

- sensor enrolls fact of some controlled event and then sends data to overall controller(microprocessor), which records received data to its own memory and waits for an airing;
- transceiver (receiver-transmitter) module in strictly defined time interval airs, transmit data, checks data delivering and shuts down and only after understanding that data have been received it switches to the sleeping mode;
- wind generator and solar panel are used for generating and transmitting power energy to the battery charger;
- storage battery accumulates energy received from the wind generator and solar panel for autonomic supply of transceiver control system;
- battery charge controller is necessary for choosing an optimal battery charging methodic and maximally possible lifetime extension.

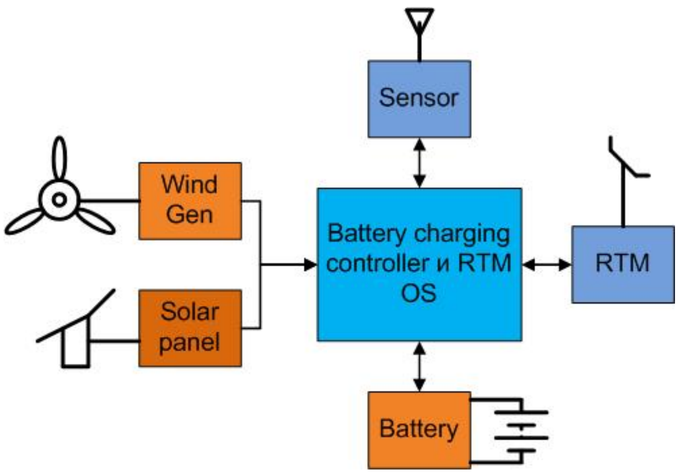

Fig.1. Autonomic power supply system structure

The use of wind gens and solar panels as a energy power source [5, 10] gives an opportunity to apply this system in different environmental conditions with various rations between wind and solar energy. The use of wind gens and solar panels as a energy power source gives an opportunity to apply this system in different environmental conditions with various rations between wind and solar energy.

The main requirement to wireless sensor network is its adaptive operation, i.e. an ability to self-adapt to the changing operation conditions, for example neighboring elements failure or low battery charge. Taking into account a vast difference of environmental conditions, where we can use the system, during autonomic power supply system designing for wireless module, it is also necessary to take into consideration next factors:

- Mote's geographic position. Various environmental conditions leads to different rations between energy received from wind gens and solar panel that changes device's operation algorithm and type of equipment used.
- Average extension of daylight hours. The system totally loses solar panel (one of the energy sources) at a nighttime period. This is a reason to restrict energy consumption for saving the stored battery charge by the increasing sensor testing interval and shifting airing moment to the beginning of daylight hours. It can help to accumulate enough energy for nighttime period.
- Current battery charge. At a certain system operation time probability of significant decreasing of energy received from autonomic sources appears with a need of energy consumption restriction charge by the increasing sensor testing intervals.

It is also necessary to emphasize factors influencing on system operation but depending on designers and consumer organization requirements, i.e. sensor sensitivity, reliability and value requirements [4]. Eventually parameter's selection will affect on total quantity of sensors and energy consumption in general.

II. BATTERY CHANGE CONTROLLER OPERATION ALGORITHM

It is necessary to take into account that battery charge controller is one of the main elements based on renewable energy source autonomic power energy supply system, that can self-adapt to environmental changes and make appropriate changes in operation mode of transceiver module. We propose an algorithm on the Fig. 2 that consider the upward fact.

This system has two threshold battery voltage level: 2.1Vpc – lower and 2.31Vpc – upper, for battery which consist of six 2V cells. System makes continuous monitoring of the main battery, wind gen and solar panel parameters, and then adapts its own operation and doesn't allow battery under- and overcharging with the use of following method. First of all battery voltage and charging current are measured. If this value is lower than 2.1Vpc and power level of wind gen and solar panel are enough, than system start intensive battery charging up to 2.31Vpc with current restriction. If received from renewable energy source power is not enough, than we make a corresponding message to transceiver module for changing the operation mode. In that case if battery voltage is in the range from 2.1Vpc to 2.31Vpc and at list one of the renewable power sources can generate required energy level than battery charges up to 2.31Vpc level with mandatory current limitation. When battery voltage level is close to 2.31Vpc than system is turned off with corresponding message and monitoring cycle starts again for preventing battery overcharging.

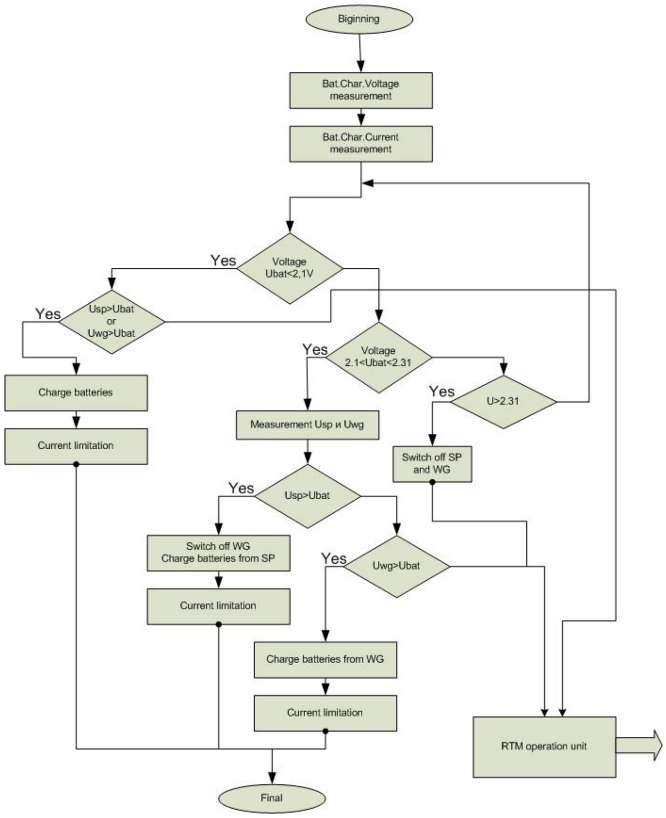

Fig.2. Battery charge controller operation algorithm

III. TRANSCEIVER MODULE OPERATION ALGORITHM

For changing the RTM operating mode that depends on current power supply system parameters condition, we have created transceiver module (RTM) algorithm (Fig. 3).

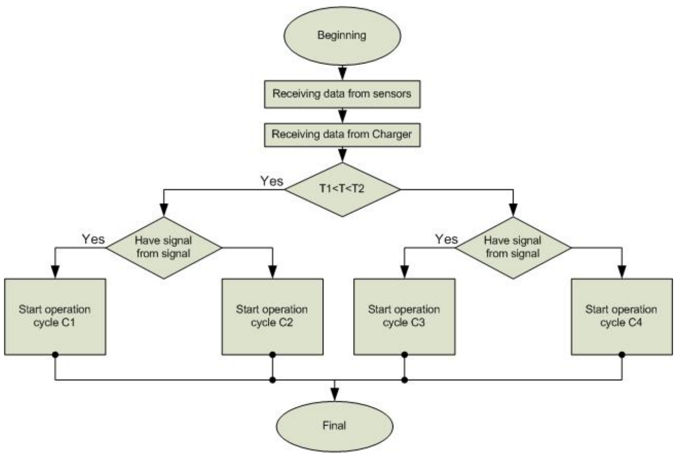

Fig. 3. RTM operation algorithm

Two threshold time ranges (T1 – sunrise and T2 - sunset) were allocated. System uses one of the following operation modes depending on message from battery charge controller:

C1 – daily energy keeping mode, during which sensor survey interval increases for keeping battery charge. In that case when battery charge controller signal has been received the system switches on

C2 – ordinary operation mode, it is active when battery charge is enough and at list one of the power sources exists: from solar panel and wind gen.

C3 – night energy keeping mode. During this mode sensor survey is cancelled for keeping accumulated energy in battery for daily airing and data transmitting.

C4 – ordinary night operation mode – sensor survey is held with specified time period.

IV. Choosing Foreground Power Source

Choosing foreground renewable energy power source (wind or sun) is also inserted into the system operation algorithm. That means if in certain area quantity of available solar energy is bigger than wind energy than it will be a priority, and vice versa. Therefore it is no need to take into account the power source that can be auxiliary in this locality. Choosing foreground power source has three steps:

First step is making an average distribution of wind and solar energy table per each region. Using weather data per exact regions we determine average wind speed uw, m/sec and average insolation per square Es, kWh/m^2.

Wind energy is calculated:

$$W_W = \frac{\rho V}{2} * C_X * u_W^2 \text{, [J]}$$

or

$$W_W = 3600 * \frac{\rho V}{2} * C_X * u_W^2 \text{, [Wh]}$$

Therefore wind energy per square is:

$$W_W = \frac{\rho}{2} * C_X * u_W^3 \text{, [W/m}^2\text{]}$$

And solar radiation energy per square is:

$W_s = E_s / t_h$, where t_h is average number of sun days per year.

	Region 1		Region i		Region n	
Relative solar energy	W_{s1}	k_{s1}	W_{si}	k_{si}	W_{sn}	k_{sn}
Relative wind energy	W_{w1}	k_{w1}	W_{wi}	k_{wi}	W_{wn}	k_{wn}

Secondly, we introduce a weighting factor k_{si} and k_{wi} for each power source (solar and wind) per each region:

$$k_{si} = \frac{W_{si}}{W_{si} + W_{wi}},$$

$$k_{wi} = \frac{W_{wi}}{W_{si} + W_{wi}}, \text{ where } i = 1...n$$

It is necessary to take into account that $k_{si} + k_{wi} = 1$.

For the third step we make a ratio's comparison and power source with biggest weight rate will be called foreground. In this case priority does not effect on required energy source power: wind gen and solar panel should be calculated on complete system load.

V. Test Controller for Battery Charger and RTM

For experimental verification we perform layout elaboration based on reconfigurable equipment MyRIO (Fig. 4)

Fig. 4. Universal programmable controller NI MyRIO

NI MyRio is a multifunctional hardware unit that consists of two processors, ten analog inputs, six analog outputs, audio channel, 40 lines of digital input/output etc.

Within the project, MyRIO is used as a controller of battery charger and transceiver module's operating system. Programming of this unit with the use of virtual software can be become reason of realization developed operation algorithm, and it also monitors system operation in real time.

The use system in this research is limited by experimental check. It is due to price (relatively lower that such equipments) but expensive enough for this project realization. Also there are restrictions on application condition. In spite of protected frame temperature operation modes are limited by 0-40 degrees, but it is not enough for use this module in Siberia for example.

VI. CONCLUSION

Proposed algorithms of power system operation take into account not only geographic positions but also data transmitting cycle with the use of the wireless channel. Developed algorithms give us an opportunity to select power energy source in automatic mode. Such renewable power energy sources as solar panels and wind gens are used for enabling a high system autonomy. Also for each region the priorities of their operation are adjusted in accordance to developed method.

Chosen for experimental check controller NI MyRIO gives an opportunity to make a qualitative system testing in a short time. Further, due to restrictions of MyRIO application, it will be necessary to develop a unique controller battery charge and RTM OS corresponding operational and functional requirements.

This work was supported by Russian Foundation for Basic Researches (project #14-07-00414).

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