Autonomous Monitoring System Harvesting Energy from Air Gusts caused by Moving Objects

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***Abstract*- In this article the hypothesis is drawn, that the remote monitoring system can be powered from the wind gusts created by moving objects. For this reason vertical shaft wind turbine and battery has been utilized to create autonomous monitoring system. The system was evaluated during one month field test.**

INTRODUCTION

Safety of any transportation system is getting of high importance with the rise of intensity, speed and number of participants. Thus various systems and technologies are used to manage the traffic problems in remote areas, such as sensors, remote terminal units, data transferring systems etc., to eliminate possibility of accidences caused by human factor[1..2].

Any monitoring system consists of network of sensors, which acquires data of the controlled object. In some cases data acquisition has to be located in areas where utility grid is unavailable. That is why the autonomous power supply is much preferable for sensor devices. For this reason some renewable energy source should be utilized for power supply of the system.

A. *Hypothesis*

As the monitoring system has to be located closely to controlled object, it is much preferable to harvest the energy available at the place of data acquisition. As the traffic participants are generally moving objects, the air shifts are caused when objects participate in traffic. Thus it could be possible to generate energy from the wind gusts caused by participants of the traffic system, meaning to use the traffic system as the energy source. As the result the wind generator could be utilized as the primary energy source for the sensor device.

SYSTEM REQUIREMENTS

As the participants of the traffic system cause turbulent air movements it is necessary to have wind generator, which harvests energy from air movements of any directions. For this reason vertical axe wind generator is utilized to meet this requirement.

Additional energy storage element should be used to provide continuous operation, during periods, when primary energy source is unavailable for some reason.

It is proposed that system should supply small loads (<2 W) during 24 h. In this case total amount of consumed energy is:

$$E = P \cdot t = 2 \cdot 3600 \cdot 24 = 172800\ J \tag{1}$$

The appropriate wind generator is chosen with following two formulae:

$$P_v = 0.5 \cdot \rho \cdot A \cdot v^3 \tag{2}$$

$$P_e = P_v \cdot \eta_t \cdot \eta_g \tag{3}$$

where P_v is power of wind turbine [W], ρ is density of the air (1.225 kg/m^3), A – area of turbine's rotor [m^2], v – wind velocity [m/s], P_e - power of generator [W], η_t, - turbine's efficacy, η_g – generator's efficiency.

Assuming that wind velocity of gust is the same as speed of moving object, measuring it in 1 m distance, then if object's speed is about 60-90 km/h (16-25 m/s), it is possible to calculate the available power for wind turbine with 1 m^2 rotor area:

$$P_e = 0.5 \cdot 1.225 \cdot 1 \cdot 20^3 \cdot 0.08 \cdot 0.8 = 313.6\ W \tag{4}$$

The amount of energy also is related with the traffic intensity and type of transport. The following calculation is done for railroad, which intensity preliminary assumed as 3 objects in hour, which passes the wind turbine during 20-30 seconds. So that the required power of wind generator has to be:

$$P_{e1} = \frac{E}{2 \cdot 20 \cdot 24} = 120\ W \tag{5}$$

Now it is possible to calculate the required rotor area of wind turbine:

$$A_1 = \frac{P_{e1}}{0.5 \cdot \rho \cdot v^3 \cdot \eta_t \cdot \eta_g} = 0.38\ m^2 \tag{6}$$

The electronic system that implements the monitoring functions has to be designed meeting high efficiency requirements, which should effectively utilize each Joule of harvested energy.

PRELIMINARY MEASUREMENTS

In order to analyze the potential of proposed autonomous energy system in certain places, the preliminary wind velocity was measurements were conducted at different places – railroad and auto road.

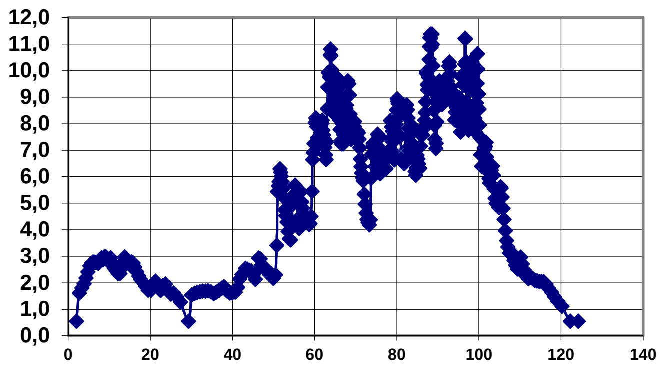

Fig.1. Wind velocity pattern of moving freight train.

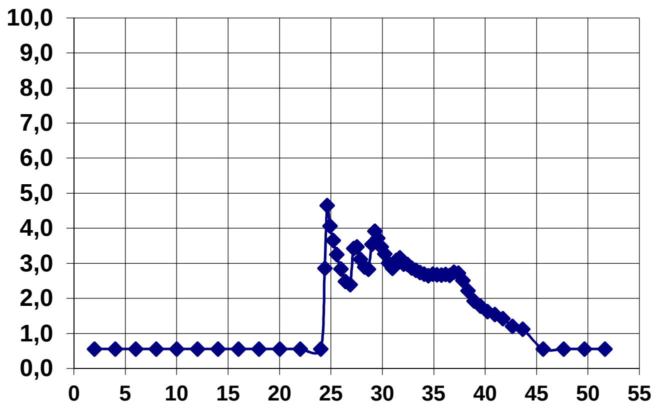

Fig. 2. Wind velocity pattern of moving electrical train.

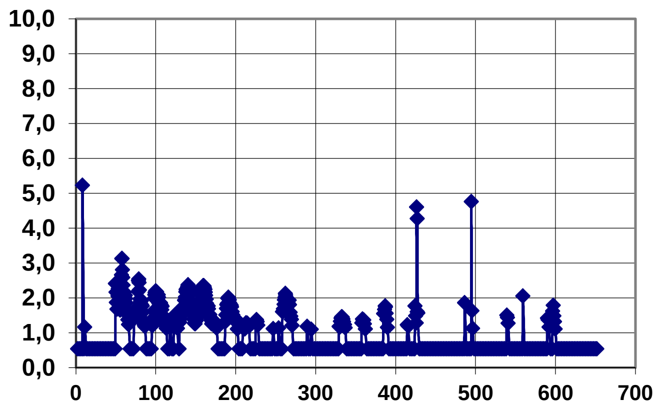

Fig. 3. Wind velocity pattern of moving freight trucks.

Energy analysis of acquired wind velocity data is presented below.

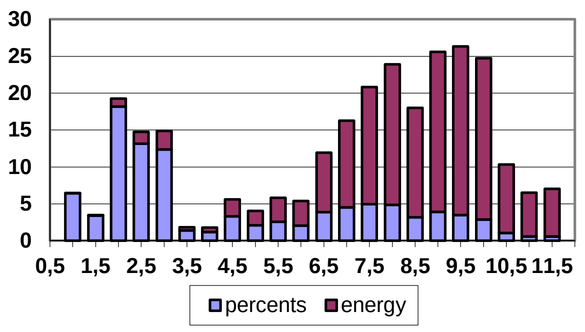

Fig. 4. Potential of energy generation from freight train wind pattern.

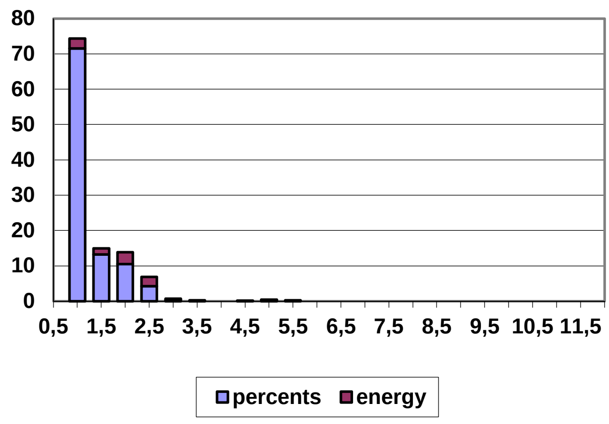

Fig. 5. Potential of energy generation from freight trucks wind pattern.

In conclusion to diagrams presented above (Fig. 1. .. Fig. 5.), the most profitable conditions for proposed system is installing on a railroad, where mostly freight trains are passing by.

DEVELOPMENT OF THE CONTROLLER

Development of the efficient charging device with maximum power point tracking (MPPT) algorithm, which allows harvesting as much energy from wind generator as possible, is one of the main function in such application, because it affects the period of autonomous operation of the remote system. Another task is to develop energy efficient monitoring equipment, which property can also prolong the autonomous operation.

The charger device is developed specially for low revolution wind generator application with the buck topology driven by microcontroller MSP430F2274.

Monitoring equipment consists of microcontroller, which monitors wind velocity and saves accumulated data into micro SD flash card. It also contains necessary elements for connection of GSM modem through RS-232 interface. The microcontrollers algorithm was chosen accordingly to previous researches provided in [3].

TABLE I

PARAMETERS OF AUTONOMOUS MONITORING SYSTEM

Parameters of autonomous monitoring system	
Nominal speed velocity	10 – 15 m/s
Minimal speed velocity	3 m/s
Maximal speed velocity	30 m/s
Monitoring system nominal power	2 W
Generators nominal power	120W
Battery's capacity	96 Wh
IP class	IP 64
Data transfer	GSM
Data storage	<4 GB, micro SD card
EMC	LVS EN 50419:2005
Control box dimensions	300x300x150 mm
Wind turbine dimensions	700x500 mm

FIELD TEST

After receiving the permission to install proposed autonomous monitoring system in certain place, it was noticed that the intensity of the train traffic and their speed at that place was not the same as that, which had been assumed in preliminary calculations. Nevertheless, it was possible to decrease the amount of consumed power of monitoring system, by changing the algorithm of the system operation – the GSM modem (which powered by 9 V and consumes 70-200 mA) was powering during the periods of sending messages by Short Message Service (SMS) only. The result was drop of power consumption down to 0.1 W.

On the picture below (see Fig. 6.) the remote autonomous monitoring system is shown, with 4 m long mast, anemometer on the top, vertical axe wind turbine and control box in the middle.

Fig. 6. Proposed autonomous metering system.

The acquired data from the anemometer are presented on the diagram below (see Fig. 8.). Each measurement was taken as an average value of wind velocity during the period of 2 minutes. As it can be noticed, that generally the average speed was not high, that was not enough to power the system continuously, but during short periods of gusts, it was possible to charge the battery and maintain more or less constant voltage on it. Daily graphic (see Fig.9) provides more detailed view of wind velocity change.

Figure 7 shows the change of battery voltage during field test that approves the autonomous operation with more or less constant voltage on the battery.

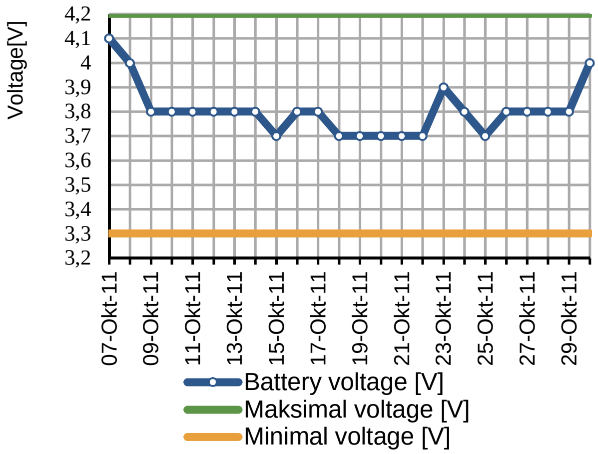

Fig. 7. Battery voltage change during field test.

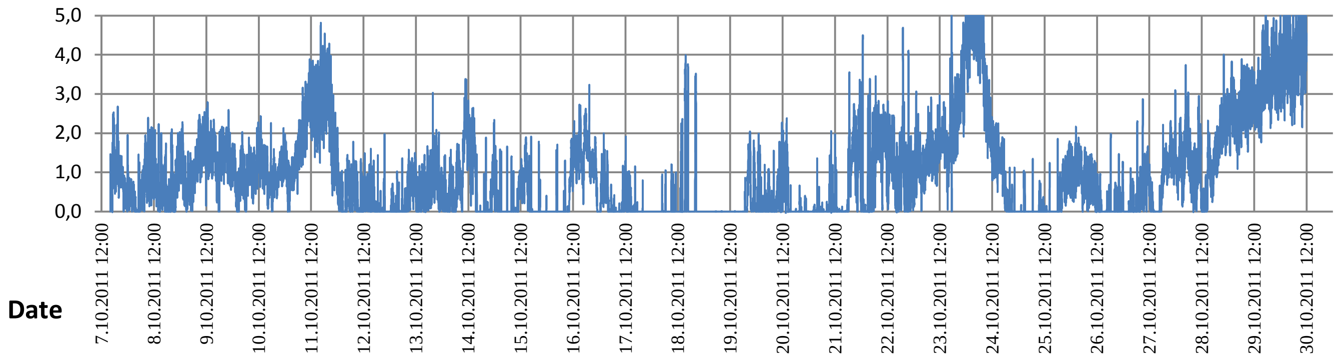

Fig. 8. Acquired wind velocity data during the field test.

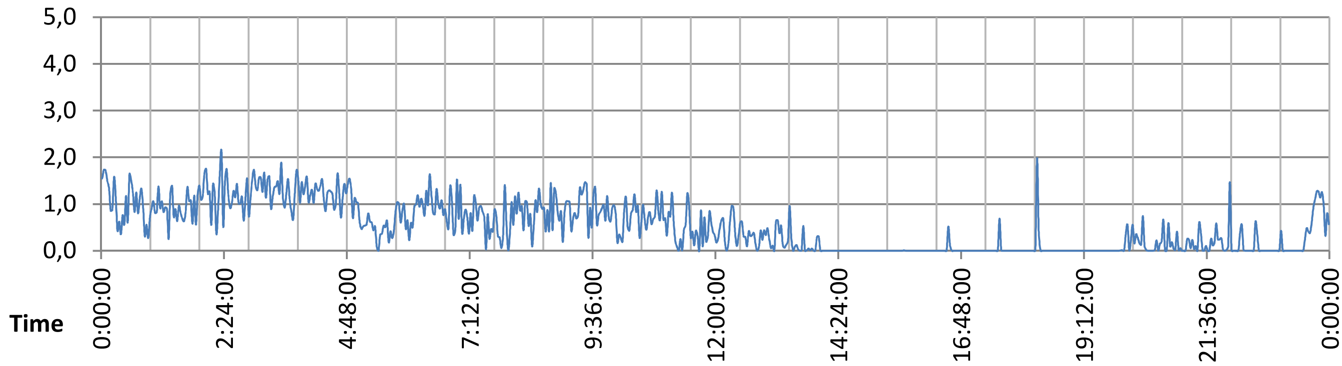

Fig. 9. Wind velocity data during one day.

CONCLUSIONS

The safety of any type of transportation are getting of high importance, which has to be monitored and controlled remotely.

The proposed autonomous monitoring system harvests energy from the air gusts caused by moving objects. Depending on the type of transport the created wind gust pattern differs noticeably, thus making suggestion of more or less successful operation in some certain case, for example freight train causes preferable air gusts (with high wind velocity and period) because of train's non-air dynamical forms.

The autonomous system has been tested during one month in certain place, which did not match preliminary calculations, that is why the consumed power of the proposed monitoring system had been cut down.

The results of the field test revealed the solvency of the drawn hypothesis and can be implemented also in different locations.

FUTURE WORK

For the future work it is planned to make field tests with nominal power of monitoring system, as well as to evaluate this hypothesis in different locations like metropolitan, tunnels and high speed roads.

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