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Application of Wireless Data Transfer Facilities in Overhead Power Lines Diagnostics Tasks

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Abstract: Now there is an acute problem of duly inspection of overhead power lines. To solve this problem, the devices with a possibility of wireless data transmission without reference to the transmitting stations that comprise a set of sensors needed to measure diagnosed overhead transmission line parameters have been developed. The use of modern electronic technologies and power supply circuits provides self-sufficiency of the devices since they do not depend on external sources of power supply and perform power take off directly from the line. Wireless data transmission is carried out by means of PAW modules. Such communication channel allows arrangement of not only inexpensive networks but also capable to self-recovery.

Key words: Wireless sensor, examination, diagnostics, monitoring, overhead power line, wireless data transmission

INTRODUCTION

At present, an operating life of overhead power lines exceed the rated values and make 40 years or more so the acute problem is duly monitoring of their condition. In addition, the service life depends on the effect of environmental factors in combination with operational loads.

Of course, there are many devices with broad options (measurement of current, voltage, sag, etc.) and they are poorly used to assess the condition of overhead transmission lines and a part of power engineering facilities on-line (Samarin *et al*., 2012; Wang *et al*., 2003; De Nazary and Werneck, 2010; Kopylov *et al*., 2015; Reshetnikov *et al*., 2015; Safin *et al*., 2015). Primarily, this is due to the organization of diagnostics data transfer into a center of their collection and analysis. Traditional data transmission methods are: fiber optics; high-frequency communications; transmission via GSM modems.

High-frequency communication, especially in distribution networks, is characterized by a significant loss and unstable operation of communication channels, even with a small length. Channel operation is exposed to a negative impact of damaged insulators, poor wiring and condition of switchgear contacts. These defects are sources of interferences commensurate with the level of a transmitted signal what may cause termination of channel operation and damage to the equipment.

The main disadvantages of fiber-optic communication lines are their high cost and also expenses for their installation and maintenance (Regep, 2006). The use of GSM channel is accompanied by a lack of ensured information delivery (voice transmission has higher priority) and as a result, a relatively low reliability; considerable complexity of building systems on the basis of a large number of devices with GSM modems.

Thus, the ever more urgent to monitor the condition of overhead transmission lines is development of self-organizing systems of devices which measure the necessary parameters with the possibility of wireless data transfer arrangement without reference to a transmitting station.

MATERIALS AND METHODS

Technique for determining the condition of an overhead power line: The following parameters need to be measured to assess the condition of an overhead power line:

- Virtual current in the wire
- Ambient temperature
- Wire sag angle
- Relative humidity

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Determination of the virtual current allows analyzing the operation mode of the line and find the location of faulty sections. By a temperature of the wire it is possible to judge on peak overload in wires that helps to prevent damage. Line icing can be controlled by measuring the relative humidity, ambient temperature and wire sag angle. Measurement of the above mentioned parameters allows control of operating modes of overhead power lines and identify dangerous modes of wires working in spans and, if necessary, to inform the operating personnel about the changes of monitored parameters (De Nazary and Werneck, 2010).

The control board is based on the microcontroller STM32F051R8T. The microcontroller on the basis of core ARM Cortex M0 is a small-sized chip with 64 leads. Processor Cortex-M0 configured for versatile very low power TSMC technology consumes only 85 μW/MHz occupying an area <12 thousand logic gates. An important advantage in terms of cost savings is the compatibility with the Cortex-M3 on the level of development tools and binaries (Zhang and Liu, 2010).

Sensor SHT25 is used for measuring humidity and ambient temperature; it is an integrated circuit which package comprises primary and secondary physical value converter, an analog-digital converter and bus interface driver I^2C which leads are connected to the like microcontroller leads.

STS21 is applied in the capacity of the wire temperature sensor; it is a thermistor switched in a bridge circuit and its analog signal is digitized by the microcontroller.

Determination of a wire sag angle is performed using the accelerometer ADXL213AE which is made as an integrated circuit package. Primary and secondary physical magnitude converters, an analog-digital converter and SPI bus interface driver are integrated on a single silicon chip by MEMS technology. SPI bus signals are connected to the like microcontroller leads.

Power supply of the board can be carried out due to power take-off from an electric and magnetic components of the electromagnetic field (Huang *et al*., 2009). The primary source of power is a current transformer with a split core mounted on a wire transmission line and the secondary winding of the transformer is connected with a bridge diode rectifier in the DC circuit where the converter is switched. Output power supply is connected to a common power bus. Another section of the secondary winding is used as a current sensor which signal is sent to the microcontroller ADC.

Data transceiving is performed by 2.4 GHz radio channel using a Process Automation Wireless (PAW) module. Wireless module is a microassembly. The

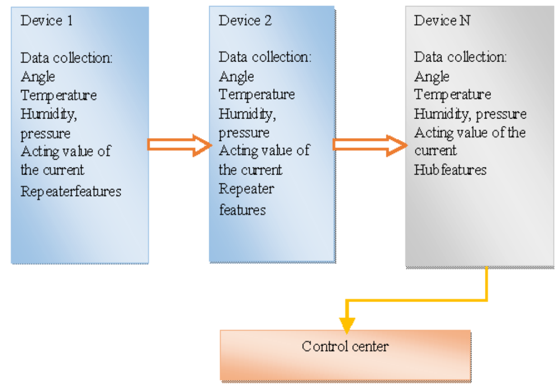

Fig. 1: Structure of an overhead transmission line condition monitoring system

microassembly is connected to the controller via UART interface. In the capacity of the wireless modules there can serve PAW embedded modules that combine high performance and low power consumption of a crystal with an effective AT-command system. They have embedded software that implements all of the basic network operations such as formation of a network, connection to the network, data retransmission and automatic network recovery. A reliable connection between adjacent devices can be carried out at a distance of up to 1000 m at their location within the line of sight what can be used in the event of failure of one or more devices, since there is the possibility to transmit information bypassing faulty units. The microassembly is powered by common power bus and equipped with an active capacitive antenna positioned on the package out of the screen. Special software will be developed for PAW modules realizing the following functions: local and remote object management; self-diagnostics of PAW modules and their communication channels; customization capability by operating personnel; network self-healing function upon loss of several components; network self-organization function; ability to manually adjust network topology (Horowitz and Hill, 2003).

Sensors mounted on the power line execute collection, pre-processing and storage data on slag angle, ambient temperature, wire temperature, ambient humidity and virtual current

A package with the collected information is formed with an indication of the sender ID. A measuring element (device) in the network located at the distant end of the controlled section of the overhead power line transmits first. It forwards a packet to the closest adjacent element. Further, the adjacent element transfers a received and its package to the next element which is located closer to the control center or data collection point (Fig. 1). Thus, a self-organizing network of devices is built; it includes sensors for measuring the basic parameters of the overhead line. Information on a line with this network then goes to storage and processing center (Horowitz and Hill, 2003).

RESULTS AND DISCUSSION

An overhead transmission line condition monitoring system developed according to the above described method consists of a specific set of hardware and metrological equipment and related software. The hardware of the platform have a distributed architecture (Fig. 2) which includes a set of sensors for measuring line wire condition and environmental parameters and also data transmission and receiving means: SHT25, humidity and temperature sensor (3-3.6 V power source, temperature measurement range: -40 to 125°C; relative humidity 0-100%, accuracy 1.8%).

Accelerometers ADXL213AE (3-3.6 V power source; operating temperature range: -40-85°C; accuracy to 0.1°) and ADXL345BCCZ (2.5 V power source, operating temperature range: -40-85°C; accuracy up to 0.25°). Microcontroller STM32F051R8T6 for receiving signals from sensors and sendingthem via radio channel (2 -3.6 V power source, operating temperature range: -40-85°C; supported protocols: IEEE 802.15.4 (ZigBee) and Z-Wave; power consumption 85 mW/MHz).

Data obtained from metrology tools are collected and transferred to a PC for further processing. The software installed on the personal computer consists of the following blocks-sag angle estimation unit, wire current measuring module, temperature and meteorological conditions prediction module, evaluation and display module (Samarin *et al.*, 2012; De Nazary and Werneck, 2010).

The prototype system is installed on the existing 35 kV line. Figure 3 and 4 present the indications obtained from the sensors for a certain period of time (21.02.2016 23:47-22.02.2016 19:05).

Figure 3 show that the temperature during the period ranged from -6.5 to -1.7°C and the humidity in the same period ranged from 73.8-90.6 g m^{-3}. Figure 4 shows that during the same period of time, the wire sag angle did not exceed 3.1° in the place where the device has been installed. These data show the ability to measure parameters of an overhead transmission line and thus to collect statistics and analyze the modes of its operation. Currently, prototype models of the devices are tested to identify deficiencies and features of operation of the devices in such a configuration.

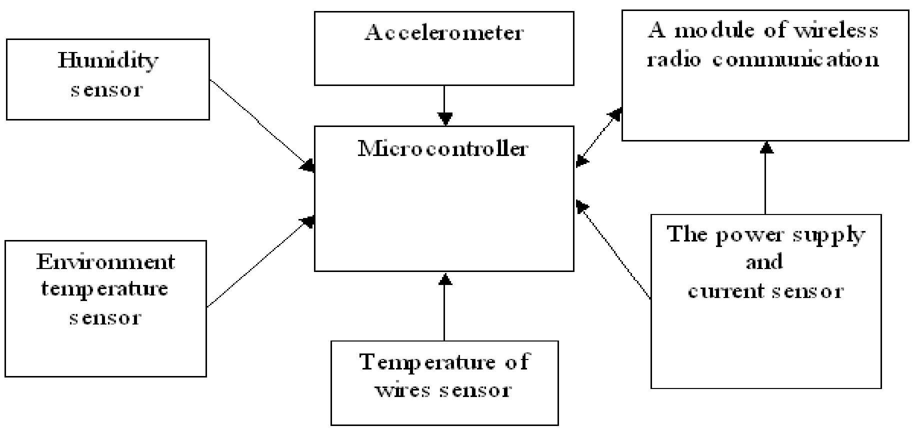

Fig. 2: The structure of a network element (device)

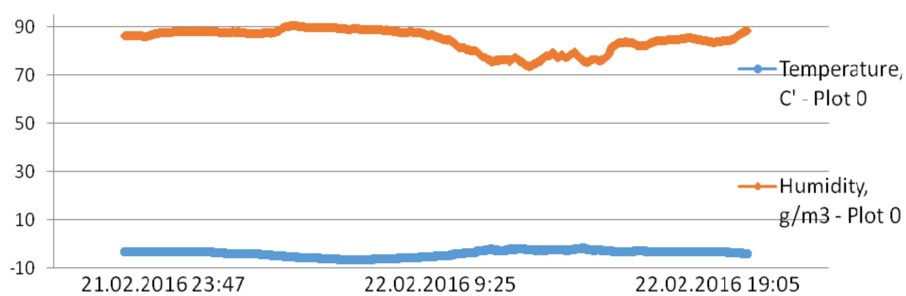

Fig. 3: Air temperature and humidity indications of the device installed in 35 kV line

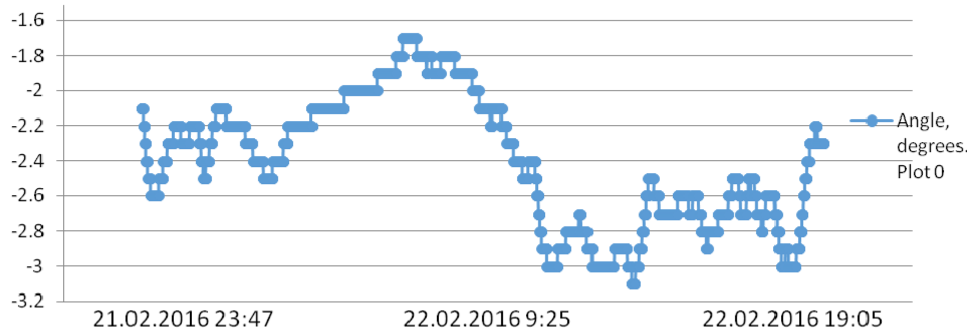

Fig. 4: Wire sag angle indications of the device installed in 35 kV line

CONCLUSION

A device is assembled by which it is possible to evaluate the condition of an overhead power line. At the same time, the use of modern electronic technologies and power supply circuits ensures self-sufficiency of the device since it does not depend on external power sources (accumulator battery) and takes power directly from the line.

Wireless data transmission is carried out with the help of PAW modules through inexpensive communication channel compliant with ZigBee protocols what does not require additional investments to maintain the channel in working condition. This communication channel allows arrangement of a network which is not only inexpensive but also able to repair itself: in a case of failure of any device, data transfer will be carried out through an adjacent unit what increases the reliability of the system as a whole.

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