Development of Arduino Based Thermal Inspection System for Hot Spots Detection in Power Lines

Miljana Milić, Sandra Đošić, Miloš Ljubenović, and Duško Lukač

Abstract – Hot spots in power lines are very common cause of damage in Power distribution and industrial environment. By detecting, locating and eliminating those critical places in time, complex and expensive equipment can be preserved, and the loss of money and power prevented. In this paper we will suggest a simple, efficient and cheap solution that solves this task. We will describe the development of one thermal inspection system for detection of hot spots in power lines, which uses a very popular open source platform for electronic systems prototyping – Arduino. The idea presented in this paper is still under implementation and though we will present the most important simulations of hardware and software parts of the system. Key benefits of such a system are: low cost, mobility, independence, low power consumption, light weight in order to be carried by a drone.

Keywords – Power lines inspection, Hot spots, Arduino, drone.

I. Introduction

Beside the application of thermovision cameras, there were not many new methods and equipment in the field of identification and diagnostics of failures in power lines [1]. Thermovision scans are regularly applied as the basic as well as the additional method for analysis of the entire power distribution systems.

Early implemetation of this method required long trainings of the inspection stuff. Beside this, successfully trained engineers were directly exposed to high voltages in the power lines and transformers. At the beginning of the year 2017, *Hydro - Québec* [2], a company that manufactures drones, developed a special kind of drone that can eliminate the problem of direct exposure of inspection stuff to high voltages. The problems that arise with this solution posed a question of the duration and the manner of the drone flight. Beside the high accuracy of fault diagnostics at the cable, some sudden and unexpected interrupts of the drone communication with the operator on the ground appeared, during the sliding of thedrone along the power cable in order to detect thermal dissipation, corrosion and other cable deviations.

Poblems with this methodology appeared in crossing points, i.e. points that represent bounds between the healthy part of the conductor, and the one that dissipate voltage (current). The current arc develops in these points, and it can lead to communication disruption between the drone and the base at the ground, which can further lead to a drone drop and damage. A galvanic separation of drone from the cable of the transmission line can overcome these side effects. Alternative approach to this kind of thermal inspections of the power line cables could be the drone that is equipped with a thermovision camera and flies in a slow flight over the cables in order to scan the temperature of them. Nevertheless, because of the inertness of the camera, a speed of the drone should be reduced in order to achieve a usable resolution of the recording, and to enable a real-time monitoring of the situation at the cable in the screen or display of the control unit on the ground. The weight of the small thermovission cameras could be another problem, since it can decrease the duration of flight by increasing the energy consumption of the drone's battery. Drones that can satisfy request for longer autonomy and possibility to carry heavy cargo, are far more expensive, unaffordable and often unavailable. With advances in electronics and thermal imaging technology, flight time duration has risen drastically, but it still involves training of the stuff to identify dissipation in the thermal image. In addition, it still requires a lot of money, because such a diagnostics set, besides the thermal camera requires the inclusion of a real-time high-resolution camera, an additional set of batteries, etc.

The aim of this paper is to present and idea of far cheaper, but equally efficient solution to thermal inspection system for drones, which is based on the Arduino environment. It could be easily affordable for small companies. The key benefits of the suggested solution are small power consumption, low weight, faster and more stable communication and real-time monitoring of the cables at the control unit on the ground.

The paper is organized in the following manner. The next section compares a traditional method for thermal inspection of the power line cables with modern, drone base ones. The third section describes the suggested concept and explains in short, the requirements of the system. Fourth section explains in detail the development of the system that includes its software and hardware parts. Results of simulations and emulations are given in the fifth section. Final remarks and conclusions, as well as the ideas for further improvement of the system are given in the conclusion.

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II. Traditional Versus Drone Based Thermal Inspections

The traditional method of measuring one such dissipation involves at least two trained persons that work on the ground; cameraman and an engineer that needs to analyze the results. This is shown in Fig. 1, [3]. The camera used in this analysis exceeds the price of 10000 euros. The measurement consists of a simple thermovision recording from the ground, and displaying of the obtained results with the proper color scale and resolution in real time on the screen observed by the person performing the analysis.

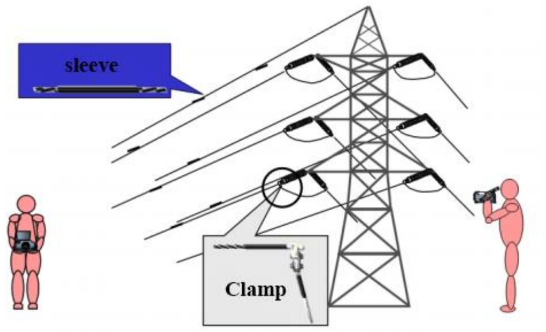

Fig. 1. Traditional method of power line dissipation analysis

Since the camera scans the area from the ground, it is possible to see only the temperature distribution, but not the cause of it, and consequently it is not possible to guarantie that the cable replacement would eliminate the detected cable fault.

After this kind of recording, a thermogram is created on a computer. The software for one such analysis costs a couple of hundred euros. The thermo-analysis results from such software are shown in Fig. 2.

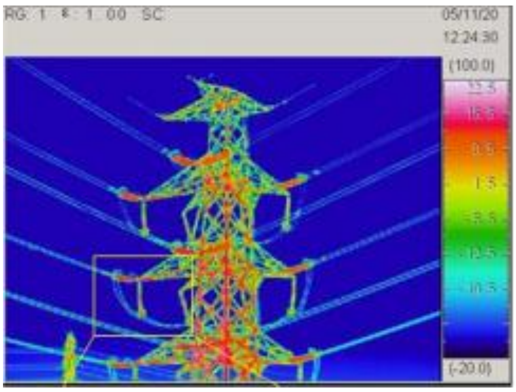

Fig. 2. Software thermo-analysis real-time view

The cost of a thermal camera plays a determining role in traditional measurement, and ranges from a minimum of $13,950 for the FLIR T540 (Fig. 3), up to several hundred thousand dollars; in electronics diagnostics, the cheapest thermal scanner costs about $500.

Fig. 3. FLIR T540

The comparison of some popular thermal cameras is shown in Table 1. Shown data are from the manufacturers' website, on December 25th. 2017.

TABLE I
Comparison of Different Thermal Camera Specifications

Type of the camera	Price	IR sensor	Resolution	Precision
FLIR c2	$500,00	80x60	320 x 240	±2°C or 2%
Flir Ex-series	$959,00	320x240	320 x 240	±2°C or 2%
Flir Exx – series	$2,799	320x240	320x240	±2°C or 2%
FLIR T540	$13,995	320x240	320x240	±2°C or 2%

A. Drone based measurement

Due to many drawbacks, a traditional method is nowadays avoided. Some of the most important ones are: the inability to determine the cause of the breakdown in the transmission line. Therefore, drones have to carry two cameras, one thermal and one camera for real-time image display. Another drone based method is one that creates a direct contact of the drone with a conductor. The thermovision cameras that must be carried by the drone can be very heavy, and thus to reduce the flight time. One of the cameras that can be carried by a drone is FLIR T640BX, and its price is $27995. The resolution of this camera is 640 x 480 pixels. The error in thermal imaging is still very similar to the above mentioned cameras.

Fig. 4. FLIR Thermocopter

The weight of this camera is 1.3kg, although it is ranked as a lighter camera, it significantly affects the selection of drones that are able to carry it, and consequently the price of the entire system. The drone carrying a thermal camera is illustrated in Fig. 4.

B. Results of thermovision measurements

During the recording, the camera forms a thermal image by measuring the infrared radiation of the object [4]. Data obtained in such a recording must be sent and processed in the computer, or directly on the camera itself. Some cameras of higher class support these features. Often, the data processing software presents a bottleneck in the analysis of the damage of the transmission line. It is very expensive, and the time to obtain the appropriate thermogram is much longer than the time for collecting the data at the transmission line.

III. The System Model

The system presented in this paper consists of two Arduino platforms that communicate with each other using 433MHz RF module. One Arduino platform is located on the drone and it is responsible of power line thermal dissipation recording. The second Arduino platform is used for data collection, acquisition and processing. We use the Processing software package for data visualization, i.e. for forming the power line thermal dissipation image.

A. The drone model

The drone model consists of the Arduino Nano platform, three contactless IR temperature sensors MLX9061, RF transmitters and RF receivers, (both operating at 433MHz) and Li-Ion batteries. We use two servo motors to change the sensors position and to provide measurement at different points.

The measured data are sent to the receiving unit on the ground, thus creating the real-time image.

B. The ground model

The ground model consists of the Arduino UNO platform, RF receiver and RF transmitter (both operating at 433MHz), buttons and switches. It is also a system that needs the battery supply. The system's task is to receive data from the drone, and to forward them to the local computer or an Android device. The communication between the local computer and an Android device with Arduino UNO platform is serial. The communication is fast enough to realize the real-time image, with the minimum acceptable delay.

C. The processing software

The data is processed by Processing software package, based on Java. The software is used to collect data from serial communication, store them in temporary fast buffers, and plot the sensor's pixel temperature image. The sensors can be moved by the servo-motors, so the software knows the pixel position and based on the measured temperature, knows the color as well as the pixels intensity. The additional time saving is done with special pixel drawing: from left to right, and from right to left. The so obtained thermal image contain data memorized in a discrete time interval.

IV. The System Functionality

The functionality of the system will be described using UML (The Unified Modeling Language).

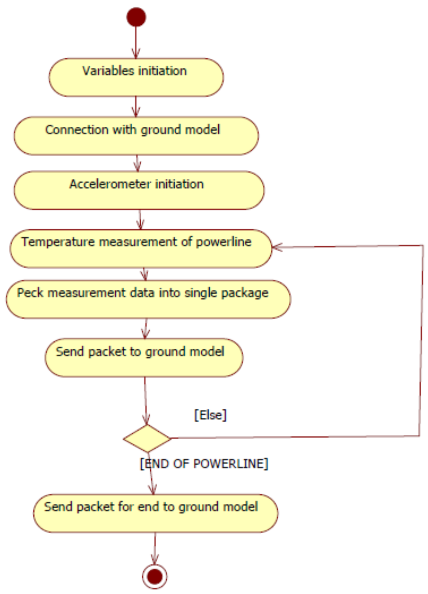

Fig. 5. Controller activity state diagram

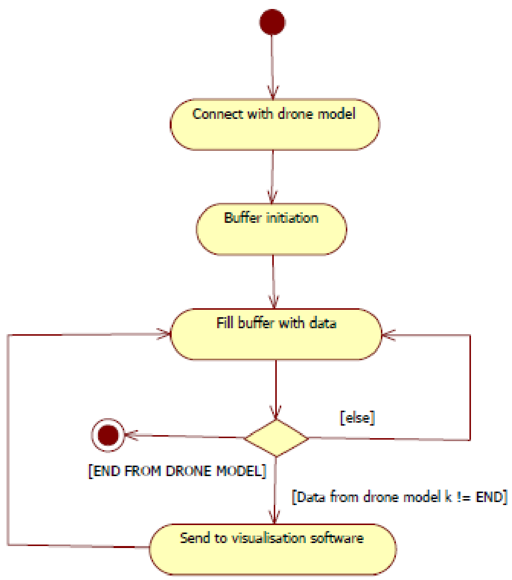

Fig. 6. The ground controller activity

UML is a family of graphical notations that help in describing and designing software systems, particularly software systems built using the object-oriented style [5]. The UML was created by the unification of many object-oriented graphical modeling languages that were succesfull in the late 1980s and early 1990s. Since the OMG (Object Management, Group), [6] adopted it as a standard, UML began to conquer the market. Today, UML is one of the most preferred languages for specification, visualization, construction and documentation of the software systems development.

Fig. 5 describes the controller activity above the power line which measures the conductor's temperature in real time, and sends the data to the processor on the ground. Fig. 6 describes the ground controller activity, which has to accept the data and forward it to the computer, or the Android device for visualization.

V. Simulation Results

The simulation was done using Proteus [7] and Fritzing [8] software packages. Results of the simulation were processed in the Fritzing software package (for displaying the entire system on the prototype), Fig. 8. Due to the complexity of the MLX90614, [9], sensor (Fig. 7), and lack of the model in Proteus software package, the LM35 sensor was used to achieve the desired dynamics and the temperature change rate in order to perform performance testing, as well as the thermal design visualization. Fig. 9.

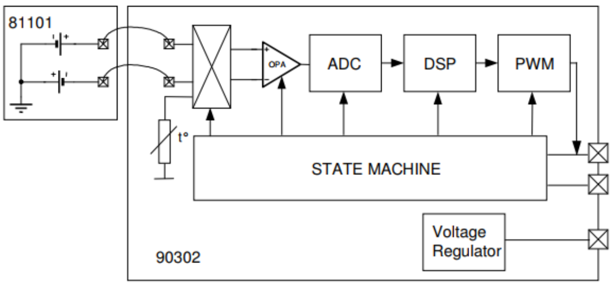

Fig. 7. Module MLX90614

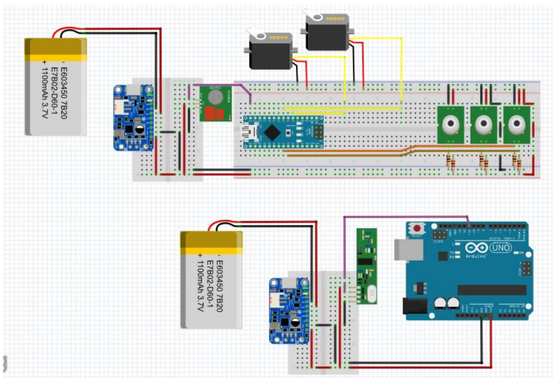

Fig. 8. Fritzing emulator

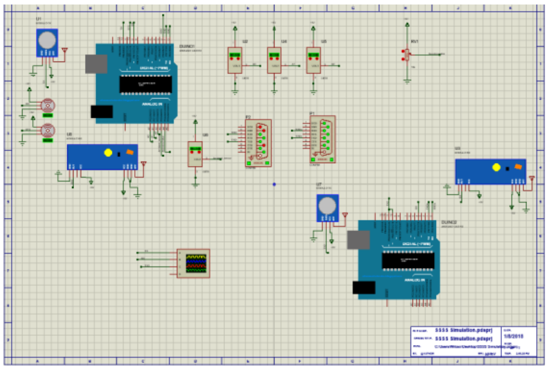

Fig. 9. Proteus emulator

Simulation models for Arduino as well as RF transmitters and receivers had to be developed additionally. The simulation inculdes collecting data from the sensors, storing them in the temporary buffer, and sending them via RF links. The first RF communication link carries information about the measurement, that is, the current temperature read by each of the three sensors individually. The second RF communication link is between pair of receiver and transmitter and it carries the control bits that allow the certain part of the image to be scanned. That was done by sending the servo engine coordinates from the ground to the drone. The first RF communication link operates at 433MHz, while the second link operates at 315MHz. ASK (Amplitude-shift keying) modulation is used for both communications links, since it gave the best results during simulations [10].

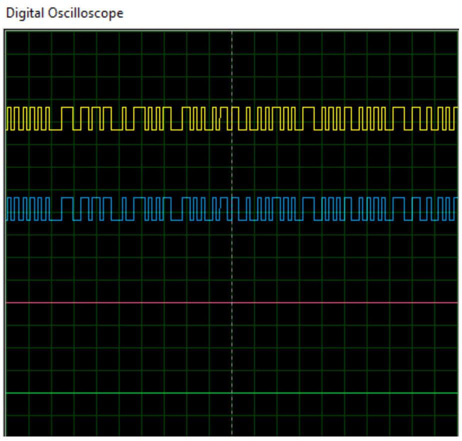

Fig. 10. Measured exchanged data: Yellow - send data, Blue - received data

Fig. 10. shows communication's speed between the drone model and the ground model. It is shown that data is accepted almost immediately after sending. This is a very important feature of the system, especially during linear scanning of the power line. In the scanning process is not desirable to skip any part of power line.

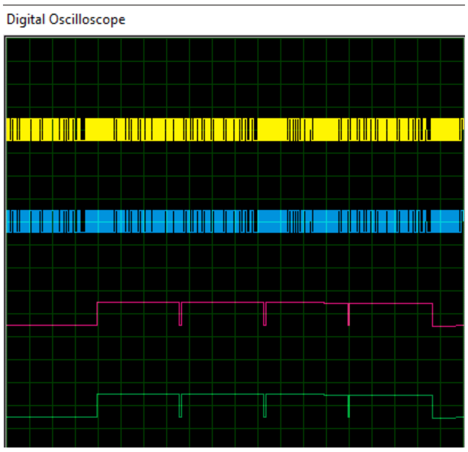

Fig. 11. Two parallel communications without crosstalk: Pink - Send control data, Green - Received control data

Fig. 11. shows communication without crosstalk, because we use buffers on both sides. The buffers are controlled by Arduino interrupts, and they depend on the communication.

Fig. 12. shows errors, when, for example, the temperature suddenly changes from 240 to 300 degrees; the error is $\pm 4^0$C [7].

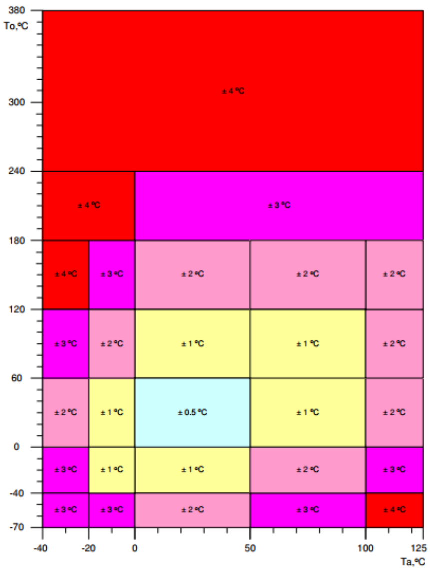

Fig. 12. Error display MLX90614 [7]

Measurement visualization software was written in the software environment Processing [11]. Processing is a Java customized software for processing data from a serial port, or from a microcontroller. The visualization software has two modes of operation. The first mode (Fig. 13) deals with static parts of the transmission line. The second mode represents a linear analysis of conductors. The software has the ability to display image from the drone's camera in a real-time, to save the image, to capture the image, and to set the thermal image over the real-time camera image.

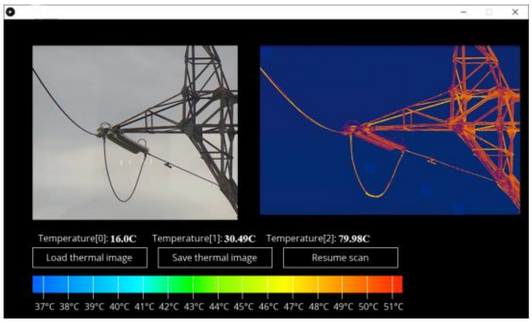

Fig. 13. The static part of the transmission line analysis

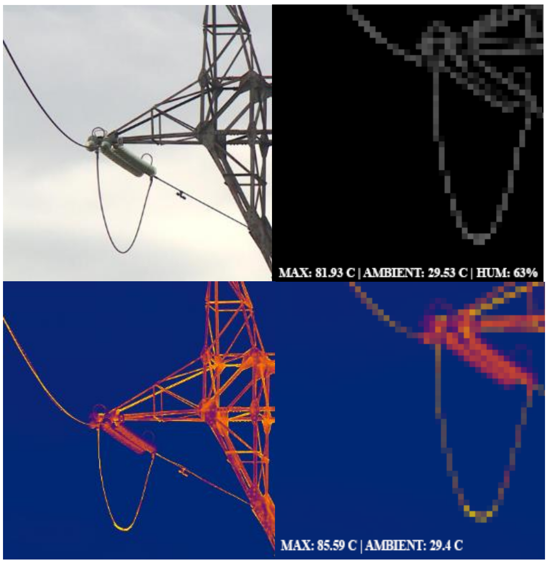

Fig. 14. Prototype images

Figure 14. shows the real-time camera pictures and the image from our model.

VI. Conclusion

In this paper, we have described the Arduino based thermal inspection system for hot spots detection in the power lines. The most important advantage of the presented system is its low price. Nowadays equipment for test ing the transmission line is very expensive which does not allow to be widely used. Considering the price of our presented system, it can be used to examine the thermal dissipation inside the house or for investigating dissipation from the central heating pipes, etc. Also, the presented solution is mobile and light weights, which allows work on different terrains especially in inaccessible places.

Acknowledgement

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