

APPLICATION OF LORA NETWORK IN PERMANENT THERMAL IMAGING MONITORING PROCESS

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Today, monitoring systems, which include the monitoring of a temperature process, are often based, partially or entirely, on the application of thermal imaging procedures. In such systems, thermogram transmission techniques are generally represented via classic LAN or WLAN networks. In this work, instead of applying the usual techniques, the thermogram is transformed into a corresponding set of temperature data that is distributed using the LoRa network.

Keywords: information system, LoRa, microcontroller, monitoring, prevention, thermal imaging

Large quantities of coal are stored for the needs of thermal power plants and city heating plants. The mines themselves also have their own landfills. Coal is stored in an open space, by piling the coal on an already existing one in the form of a cup or a prism, with steep sides. In the coal storage process, the phenomena of self-heating and self-ignition are extremely important, which can cause the deterioration of coal quality and a whole series of problems, and even an interruption in the operation of thermal power plants. In addition to production and economic problems, the ecological aspect is also very important [1].

Research in this field is intensively carried out in the world [2]. The obtained results and mathematical models are encouraging, but there are still many unsolved problems. Practically every warehouse is a problem in itself, due to a number of parameters that affect self-ignition. That is why the parameters of the specific warehouse are monitored, existing mathematical models are modified, or new ones are set up, and based on the results of measurements and modeling, solutions are proposed to suppress the occurrence of self-ignition. Self-ignition of coal occurs in the presence of oxygen and when the heat produced is small but sufficient to cause a reaction between the coal and oxygen, and there is no adequate dissipation by conduction or convection, so that the temperature increases within the coal mass [3]. If a sufficiently high temperature is reached, self-ignition occurs, which requires a sufficient amount of stored coal and a certain degree of ventilation.

By monitoring the relevant parameters and developing a suitable mathematical model, it is possible to predict the behavior of coal storage in different circumstances. In this way, the occurrence of self-ignition of coal can be reduced. Even in such a situation, and especially in cases where there is no monitoring of essential parameters, thermal imaging surveillance should be applied. It is a very effective way for the early detection of hot spots, which are of great importance in the early prediction of coal self-ignition. Such thermography monitoring systems, in most cases, are based on the transmission of the entire thermogram from the recording location to the monitoring center via a suitable computer network based on the use of classic LAN or WLAN technologies. Sometimes, instead of the previously mentioned computer networks, broadband cellular networks (mainly 3G or 4G networks) are used to transmit thermograms. Although the previously mentioned solutions are most often used during the construction of the mentioned systems, this does not mean that they are the only ones possible for implementation in the specific conditions of monitoring and prevention of coal deposits self-ignitions. Traditional solutions include the transfer of the entire thermogram from the recording site to the monitoring center, where the given thermogram will be

further processed and analyzed in order to obtain specific conclusions necessary for early detection of potential self-ignition of coal deposits.

In the following lines, a solution is presented that places the primary processing of the thermogram at the source of the thermogram, that is at the thermovision recording site, so instead of the entire thermogram, only the corresponding subset of the needed temperature data is transmitted to the monitoring center. This solution enables the application of other data transmission solutions to the monitoring center instead of the mentioned traditional ones (LAN, WLAN and others).

Description of the realized system

The basic components of the implemented system are shown schematically using the appropriate level of abstraction in Figure 1. As can be seen from the given schematic representation, the system is composed of two basic units. Within the first unit, there is all the equipment necessary for the realization of thermal imaging in the assigned areas, that is, in the locations where there are coal deposits that need to be constantly monitored. The second unit is a monitoring center where data from all locations where thermal imaging is performed are collected for the purpose of final analysis of those data sets and obtaining appropriate conclusions for the purpose of early detection of possible self-ignition of observed coal deposits.

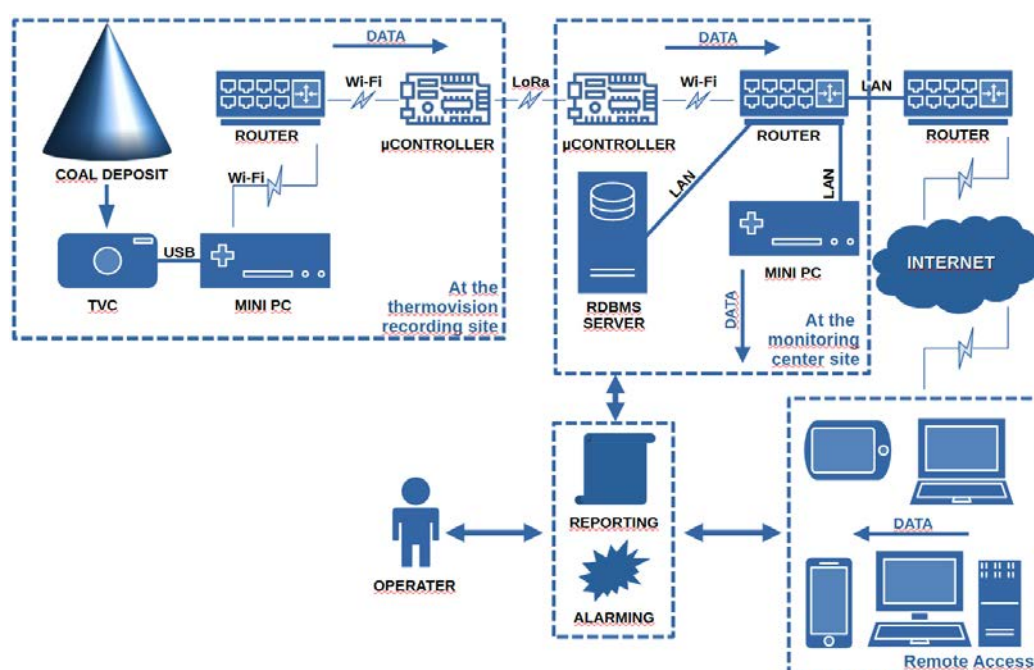


Fig. 1. Simplified schematic representation of the main system components

Thermal imaging cameras of different types, characteristics and manufacturers can be used within the considered solution. Thermal imaging cameras form a thermal image by measuring the infrared radiation of a specific body or the entire scene. The software, which the camera contains, performs the necessary correction during the conversion of the thermal image into a suitable thermogram, which represents an approximation of the exact temperature of the recorded object, or the temperature distribution in the scene, in a wide temperature range, whereby the temperature distribution of the recorded surface is displayed by color variation [4, 5]. Continuity of thermal imaging is ensured by the development of special dedicated software that provides thermal imaging monitoring in real time. The implemented software enables the creation of a thermovision video record from the observed thermovision camera, whereby a suitable thermographic image can be extracted from the observed record at any time, that is, there is a possibility of extracting partial thermograms that are subjected to further temperature analyses. The software allows adding the functionality of continuous thermal imaging even in cases where this functionality is not originally implemented in the thermal imaging camera itself, so accordingly there are no restrictions on which type of thermal imaging camera will be used when implementing the observed technical solution. Continuous thermal imaging by

itself will not mean much if there is no possibility of adequate interpretation of the obtained thermograms. For this purpose, a special dedicated software was created that translates thermograms into the appropriate set of temperature values. Within each thermogram there is an incorporated temperature scale for the given thermogram. The software first analyzes the temperature scale and encodes the set temperatures in relation to the color based on the minimum, maximum temperature and height of the temperature scale. After encoding the temperature scale, the software is able to perform an analysis of the entire thermogram and the translation of the recorded within the thermogram into numerical values representing the specific recorded temperatures, where the translation is done pixel by pixel. In this way, one consistent set of data is obtained that represents all the recorded temperature values at one location covered by the thermal imaging camera. After this process, the obtained set of data is transmitted to the place where further necessary analyzes will be performed for the purpose of detecting potential self-ignition of coal.

Data transmission is carried out using appropriate communication hardware and defined protocols within a special software solution intended for sending data from the observation point and receiving data in the appropriate command center. For these purposes, microcontrollers based on the ATmega2560 chip were used [6]. The connectivity of the microcontroller with the thermal imaging system at the location of the recording was performed using a solution based on the ESP8266 chip [7], which enables wireless data transfer between devices using a standard Wi-Fi network, since data transfer is achieved at a very short distance. Data transmission from the recording location to the command center is based on the use of a solution based on the RF96 chip [8], which enables data transmission using the LoRa network. The LoRa network was implemented in this case in accordance with the requirement of data transmission over longer distances, which in some cases can be several kilometers, using low transmission powers. In accordance with the European standards for data transmission using LoRa networks, transmission using the 868 MHz LoRa network was used, which is allowed for free use in the European broadcasting area. During the implementation of the LoRa communication infrastructure, antennas intended for the transmission of LoRa signals at the mentioned 868 MHz length of 90, 275 and 550 mm were used, which did not require the realization of special antenna poles for mounting them and which enabled during testing to achieve a maximum signal range of an average of 2.5 kilometers. Depending on the configuration of the equipment used and the configuration of the terrain on which the transmission is carried out, greater distances can be achieved. It should be noted here that when testing this type of data transmission in real working conditions, it was found that the entire data transmission is carried out in accordance with the defined transmission parameters and that there are no transmission losses. As for the parameters that characterize the signal itself, such as its attenuation, all parameters are within the permitted ranges and no case was recorded during the connection monitoring in which any of the parameters approached the limit values. It should be noted here that the testing was carried out both for powering the microcontroller with a constant source of electricity and for powering the microcontroller with a battery source, where in both cases a voltage of 5V and a current of up to 1A were applied to the input of the microcontroller, and that in both cases identical data were obtained. Accordingly, it was established that the data transfer is fully carried out in the intended manner, which confirmed the possibility of using this type of data transfer in the solutions implemented in this way.

In the command center, the received data from all observation locations is received and further analysis of the data is performed in real time. Recorded temperatures are analyzed in relation to defined limit values. Through the appropriate interface, the operator is able to track events at all locations where thermal imaging is performed and to have insight into the current state of those locations in real time. Here we distinguish three key pieces of information that the system provides to the user. Since a clear and unambiguous mapping of the locations of thermovision observations was previously carried out, the operator has an insight into the minimum and maximum recorded temperature values for each of the observation sites at all times. This view is realized in real time, but it is also possible to view the minimum and maximum recorded temperatures in a user-defined period. If the observed values approach the defined limit values, a corresponding notification is issued to the operator. In the case of equating the observed values with the limit, a warning is issued to the operator that a critical level has been reached, while in the case of exceeding the defined limit values, an appropriate alarm is sounded and an appropriate pre-defined action is taken. During the testing of the solution, this action was given in the form of alerting the appropriate services to the possible occurrence of an incident situation in the form of self-ignition, while in specific cases, depending on the location where permanent thermal imaging surveillance is performed, the installed equipment, protocols and other relevant factors, it may implement and automatic start of an installed protection system, if such

exists. All recorded temperature values are recorded within the capacity of the system in the appropriate relational database that is implemented within the appropriate relational database management system. In this way, it is possible to carry out further analysis of the recorded data, thereby gaining a better understanding of the processes that take place within the observed location itself, and therefore making appropriate corrections to the overall approach, which enables the system to better respond to continuous changes in the environment in which it is located. Within the interface, the operator is also enabled to monitor the operating parameters of the entire system in order to adequately and timely respond to possible problems in the operation of parts of the system or the system as a whole. Accordingly, various log files were created that allow adequate insight into the system, detection of errors in the system and appropriate reaction to the occurrence of those errors (eg loss of connection with the thermal imaging camera, problems in data transmission, weakening of the signal in the LoRa network, etc.).

Conclusion

As can be seen from the above, the mentioned solution abandons the traditional approach of permanent thermovision monitoring, in which distribution of entire thermograms or thermovision video material is carried out through the entire network resources. Now, at the source, the thermogram is transformed into a suitable set of temperature values, which are then transmitted through the network to the appropriate place of further processing. This opens up space for the application of network technologies that are much more suitable for use in such systems where high transmission speeds and large amounts of data are not required (LoRa and similar networks that are mainly used in IoT), as is the case when we need to transfer multimedia content (image or video) where LAN and WLAN solutions are still dominant. In this way, permanent thermal imaging surveillance is transformed into a solution of much wider applicability, especially in specialized industrial conditions, specific field configurations and the like, where it reduces the complexity of implementation.

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Застосування мережі LoRa в процесі постійного тепловізійного моніторингу

Сьогодні системи моніторингу, які включають спостереження за температурним процесом, часто частково або повністю базуються на застосуванні тепловізійних процедур. У таких системах технології передачі термограм зазвичай представлені за допомогою класичних мереж LAN або WLAN. У цій роботі замість застосування звичайних технологій термограма перетворюється на відповідний набір даних про температуру, який поширюється за допомогою мережі LoRa.

Ключові слова: інформаційна система, LoRa, мікроконтролер, моніторинг, профілактика, теплобачення.
