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A SYSTEM FOR OUTDOOR FIRE DETECTION AND SUPPRESSION

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ABSTRACT
There are many methods concerning outdoor fire detection. In this work a simple system for early fire detection as well as suppression is proposed, implementing GSM technology and sensors consisted of heat-sensitive cable loops. The proposed system activates instantaneously fire pumps as soon as the fire incident occurs. Also a method for the calculation of the incident's location is given.

KEY WORDS
Wildfires, fire guard system, fire detection, fire suppression, remote control.

1. Introduction

In order to deal with wildfires and outdoor fires in general, systematic provision needs to be taken concerning: a) prevention (mainly: mapping, fire zones construction, points of manned stations, points of automatic fire stations etc), b) suppression (such as cooperation of the fire suppression task forces, accumulation of meteorological information, geographical information systems, preventive estimation of outdoor fire evolution etc) and regeneration – management of the burnt area [1, 2].

There are several sensors available for fire detection [3, 4]. Consequently there are several systems deployed integrating one or more of these several types of sensors. Smoke detectors take advantage of the reflection of solar radiation due to the smoke [5]. Infrared sensors utilize the produced infrared radiation to detect fire presence [6, 7]. In the case of fire detection by the utilization of radar and laser technology the detection of fire incident, is achieved by analyzing data concerning the turbulences of the air above the monitored area, and the fire by-products levels [8-10]. These systems have limited practical implementation due to the high cost of their supporting technology. Another type of fire detection is utilizing satellite systems - sensors. The detection of smoke and fire is taking place in a computer mainframe of high computational power and it is implemented by means of an advanced algorithm that facilitates the localization of any fire or smoke incident, based on the parallel comparison of a big amount of photomaps and having as point of reference the normal photomaps of the supervised landscape. Other remote sensing systems gather information indirectly through the spectrum of electromagnetic radiation. The utilized radiations are ultraviolet, optical, infrared and microwaves. The problems that need to be addressed in remote sensing are scattering and absorption of radiation [11, 12].

In this work the concept of a fire guard system concerning outdoor fire detection and suppression is presented, that can be of use and operate independently or supplementary to the above mentioned systems. The sensor used in this system, is a formation of several cable loops that surround areas of land. The cable loops consist of linear heat detection cable [15] that responds to abnormal temperature rises and thus prevents fires, equipment damage etc. It is used in a manner that activates a control unit which integrates GSM technology [16] providing all the advantages that a GSM network can supply depending on the occasion and the deliberateness of the fire system's use (notification and alarm via cell phone, remote activation and control of a fire pump or a network of fire pumps, remote interruption of an automatic electric power switch etc).

2. Description of the proposed fire system

The temperature developed during outdoor fires (bushiness and trees) is in the order of 750÷1000 ^{o}C [13]. As it is known from occasions of electric power distribution lines being in a fire environment and exposed in these high temperatures abruption of the aluminum conductors may take place due to the melting point temperature of aluminum that is on the order of 660 ^{o}C [14]. Due to this experience the fire detection and protection of an outdoor area of several square kilometers can be obtained through the use of a surrounding conductor that could melt every time a fire incident takes place thus activating an electric or electronic circuit that could power on several fire pumps or transmit alarm signals (optical, acoustic, telephonic or any combination of them depending on the occasion) respectively.
A depiction of the concept is given in figure 2.1.

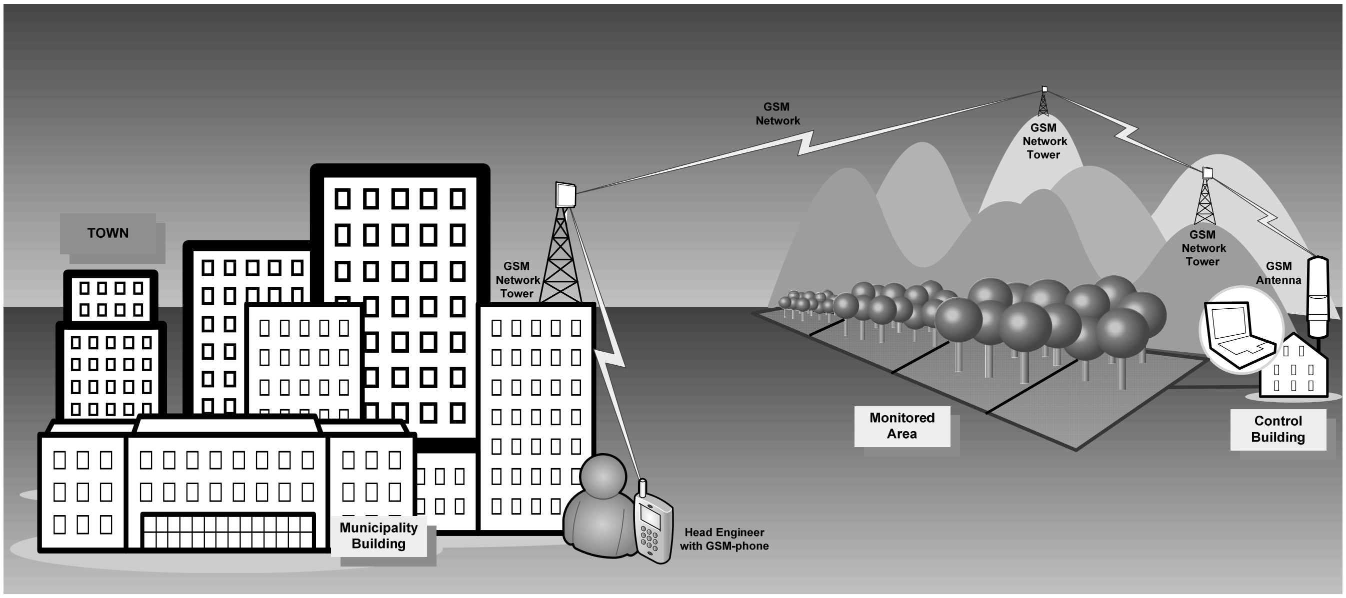

Fig. 2.1 A depiction of the fire system concept.

A simplified block diagram is given in Figure 2.2.

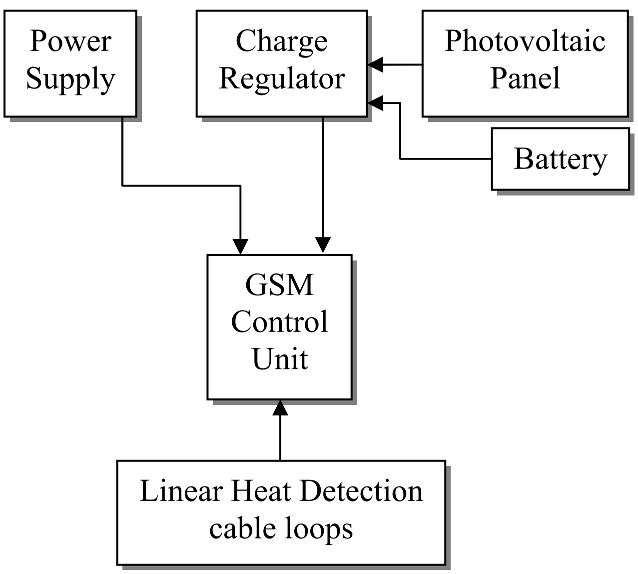

Fig. 2.2 Fire System's Block Diagram.

The system consists of three different parts as illustrated in Figure 2.2.

(1) The power part that powers up the pumps and fire engines installed in order to suppress the fire, as well as the electronic control circuitry that is needed in order to activate the pumps when the sensors detect a fire incident. It includes a provision for partial autonomy of the system through the implementation of a photovoltaic power system that provides 12 Volt dc voltage to the electronic control circuitry, suitably calculated to provide three days autonomy without sunlight.

(2) The control unit that integrates GSM technology, designed to send sms messages, or to make unanswerable calls to predefined phone or cell phone numbers, as soon as the sensors detect fire and activate it. These numbers are programmable into the control unit via a computer that connects to it in a straightforward manner via RS-232 interface module, or remotely via a cell phone using suitably constructed programming sms messages. Along with the alarm notification that the control unit provides to the fireguard department or to any other phone of choice, it also powers on the pumps for the suppression process instantly by the time the fire is detected. Another option of the control unit is that it provides remote control on every pump of the suppression system through one or more preprogrammed cell phone numbers in case of false alarms or occasions of authorized intervention to the suppression system from a designated person. Furthermore special provision has been taken during the design process so that the control unit responds to every remote operation, by sending confirmation sms messages to the user's cell phone number.

(3) The sensors part that consists of specially designed and shaped loops of linear heat detection cable [15]. It creates variable loop formations in order to shape fire safety zones according to the practical needs and the morphology of the area protected by the fire system. Their primary function is to detect the fire incident instantly and reliably and to activate the control unit as soon as it takes place.
Photography of the fire system's physical implementation is given in figure 2.3.

Fig. 2.3 Fire System's physical construction.

3. Linear heat detection cable

The sensor being used in the system is one of a class of devices that detect and respond to heat. It is known as the line-type heat detector and heat - sensitive cable [15]. The basic construction of all these devices consists of two or more strands of wire separated by insulation within a long thin cable. Whilst they sense temperature, they do not in fact provide an output measurement of temperature. Their function is to respond to abnormal temperature rises and thus prevent fires, equipment damage etc.

At the core of the heat sensitive cable there is a twisted pair of extremely low resistance, tri-metallic conductors, sheathed in new advanced thermal polymers. These polymers are chemically engineered to break down at specific fixed temperatures allowing the twisted conductors to make contact and initiate an alarm without any calibration for changes in the ambient temperature.

There are several maximum ambient installation and alarm temperatures of the heat detection cable that can be used depending on the installation site and the environmental temperature conditions.

4. Calculation of the fire incident location

For the completion of the proposed fire system, a way to calculate the exact location of the fire incident that caused the short circuit of the wires is presented, in order to provide the required info for repairing the cable loop after the fire suppression. Firstly the installed loop of heat detection cable must be scaled and calibrated during the installation process, so that it will be easy to specify the exact length on the loop at every location, taking under consideration the variable loop's formations in order to shape fire safety zones according to the practical needs. A model of the physical problem should now be laid out using its actual parameters.

It is supposed that the heat detection cable run spreads from area (A) to area (B) and has a total length of L (km). It has also a known listed resistance per unit length, ρ (Ω/m), but as the actual value of ρ is the one evolved in the model, - taking under consideration that its nominal value changes due to the fire temperature [14], - ρ will be calculated as well throughout the solution of the model considering it as unknown. After the fire incident supposing it breaks out at location X (km) counting from the beginning of the cable run at area (A), a short circuit is being developed X (km) away from area (A). This short circuit appears as an equivalent short circuit resistance, r (Ω). This is the model and its equivalent circuit is illustrated in figure 4.1.

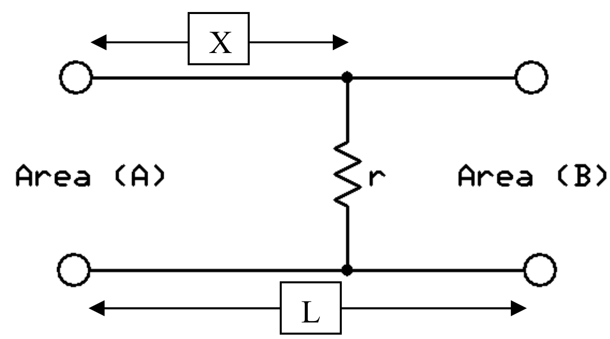

Fig. 4.1 Schematic circuit model.

The only known parameter in the problem is the length of the cable run L (km) and so ρ (Ω), r (Ω) and of course the location X (km) need to be calculated.

The procedure to follow is to measure with an ohmmeter the one end of the cable run while the other end remains open circuited. Let's assume that R_A (Ω) is the measured resistance from the end at area (A) having the end at area (B) open circuited and R_B (Ω) from the end at area (B) having the end at area (A) open circuited. By applying dc voltage V_A (Volt) at the end of the cable at area (A) the voltage at the other cable end at area (B) is being measured with a voltmeter of very high internal resistance. It is assumed to be found V_B (Volt). Simply by inspection of the circuit model the following basic equations can be constructed concerning for the measured resistances:

$$R_A = 2 \cdot \rho \cdot X + r \quad (1)$$

$$R_B = 2 \cdot \rho \cdot (L - X) + r \quad (2)$$

By summation these equations result to the following equation:

$$R_A + R_B = 2 \cdot \rho \cdot L + 2 \cdot r \quad (3)$$

Taking under consideration the very high internal resistance of the voltmeter (nominal resistance value per meter of a typical heat detection cable is 0.164 Ω), it can be safely assumed that the measured voltage V_B (Volt) at the end of the cable at area (B) is equal to the voltage Vr (Ω) across the resistor r (Ω) which is the equivalent resistance of the short circuit. From voltage division and by substituting V_B (Volt) with Vr (Ω) it is concluded:

$$r = \frac{V_r}{V_A} \cdot R_A \quad (4)$$

From equation (4.3) using equation (4.4) ρ is calculated:

$$\rho = \frac{V_A \cdot (R_A + R_B) - 2 \cdot V_r \cdot R_A}{2 \cdot V_A \cdot L} \quad (\Omega/\mathbf{km}) \quad (5)$$

Now having found ρ, r in terms of all known parameters and equation (4.1) can be used to calculate the location X (km) of the fire incident that resulted to the short circuit of the cable. Consequentially:

$$X = \frac{(V_A - V_r) \cdot R_A \cdot L}{(V_A - 2 \cdot V_r) \cdot R_A + V_A \cdot R_B} \quad (\mathbf{km}) \quad (6)$$

5. Conclusion

In this paper a new system for outdoor fire detection and suppression was proposed. Consisted of reliable components it can confront the outdoor fire incident at a fairly early stage as it is activated directly by the fire, providing an encouraging point for the system's performance and efficiency. Taking also under consideration its rather low estimated implementation cost and the easiness of installation, it is expected to contribute towards the fire confrontation either independently or supporting any other fire protection systems already implemented. The proposed fire guard system is designed for outdoor use and it aims to protect critical facilities or large areas of land. Furthermore, the system may prove capable to facilitate individuals aiming at the protection of their fortunes and critical infrastructures from fire, as well as public or private organisms, municipalities, urban centres hotels and others.

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