An automat system for monitoring atmospheric charging – construction, calibration and modeling

C. Buzduga, A. Graur, C. Ciufudean and V. Valentin

***Abstract*—** This paper proposes an electronic system for monitoring atmospheric electricity charging. Our monitoring and warning system detects an electric field which has very high potential difference between clouds and ground. Our system basically compares the atmospheric electricity with a reference value. If the detected value exceeds the reference value the monitoring system will activate the warning circuit, and in case of imminent danger (e.g. the atmospheric electricity exceeds the maximum admissible value) our system can interrupt the power supply of the protected building. This system has several advantages: monitoring permanent atmospheric charging, very simple, low cost, easy to use and does not require specialized personnel but anyone can use.

***Keywords*—**Automat system, atmospheric charging, storm, thunder, lightning, electrical discharge, antenna.

I. Introduction

THE proposed continuously monitors the atmospheric electric field at ground level, having as main purpose timely warning of his significantly increases. There are two principles for atmospheric electricity discharges detection: first is the detection of electromagnetic pulses issued by the lightning and the second one is monitoring of atmospheric electric field. The first method is the most common and is often used in weather stations, but despite the fact that it is very useful it cannot constitute basis of a system warning in a good time. For this reason, monitoring and warning system is based on the second method. The monitoring and warning system can detect an electric field unseasonably high or very high potential difference between cloud and ground. All storms are a common factor namely the high atmospheric electric field, with ease exceeding the maximum limit. Under certain temperature conditions are observed thunderstorm cloud formation specific conditions. These clouds formed above the ground are positively charged in the upper surface while their base surface is negatively charged and this form a large dipole reference to the ground surface. Under the effect of negative charges from the cloud base, which exist permanently, the electric field at ground level inverts and the value rise rapidly to 10 – 15 kV/m, in which case the discharge to the ground is imminent. One day in normal weather conditions this field is 100 V/m, with a maximum value of 135 V/m. The first phase of a thunder is a faint pre-discharge, which arises from the cloud and down to earth in increments of a few tens of meters (the descending leader). With the approach of the descending leader, atmospheric electric field discharges at ground level greatly increases, especially observing the asperities in the form of a leak blue current. While the leader is close to the ground due to the corona ionization effect the discharge becomes ascending, forming the ascending leader. When one of ascending leaders encounters a descending leader will be borne a conductive channel, highly ionized, through which flows a current of high value. When our system detects a potential slew rate of 170 V/m it interrupts the electricity supply in order to protect the home appliances, by triggering a protection relay.

Lightning rod is a metallic device placed on the top of the building that helps protecting the building against lightning. If a cloud passes over the electric charge will be attracted to the basis of the cloud and the triggered lighting will be directed through the rod device to the ground, and so will be protected the building. When clouds are based on a positive region, the phenomenon is reversed negative charges flowing on to cloud lightning. Such processes are exposed rare due to the fact that should be low altitude cloud [3,4,7,8].

For grounding rods using three copper in the shape of goose paw at least two meters apart and five meters from the building, each firmly connected to the wire rope descent. There should be at least two diametrically opposed lowering or even more if building area is great. It's good to be one of descent near the electrical panel of the housing supply because it must be connected before the inlet, lightning protection system.

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Copper or aluminum? Use aluminum especially if the roof is of tinplate or aluminum foil. However, aluminum is prohibited where it can come into contact with calcium or alkali-based paints. Do not ever use the grounding electrodes made of aluminum. For aluminum grounding will use copper electrodes. Wire rope downhill aluminum will be connected to a copper through a special bimetallic connector, and will go on copper to earth electrode. Lightning rod grounding will be bounded to the building, gas pipes; the air conditioning system at all is metal and come in the building, so that all is at the same electrical potential. It is good solder connections are made and not mere mechanical connection which can oxidize over time [6].

The content of the paper is as follows: in section 2 we describe the constructive and functional principles of our system; section 3 explains the calibration procedure of our system and we conclude with some operational remarks.

II. EXPERIMENTAL SETUP

In order build the atmospheric electricity monitoring system we used minimum set of electronic components that offer the advantage of easy operation, all devices having a low cost price. The system block diagram is shown in figure 1.

IC4 block is a voltage stabilizer type LM 7805, and realize power supply for the control bond of our system. The main component of the system is represented by block amplifier IC1, an amplifier "rail to rail" type MCP 6022 equipped with an antenna.

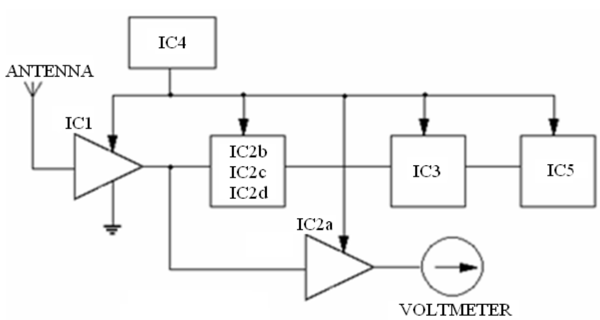

Fig. 1 System block diagram

The system has three operational states, supplying alternatively three LEDs, controlled by the block decoder IC3. Thus, when the atmospheric electricity is low, the green LED will light, and when it increases the LED will turn yellow, and when the potential difference between the cloud and the ground is very high, the red LED will light, triggering a relay block shown in figure 1 by IC5, which will interrupt the power supply to the building. IC2 is a comparator block type MCP 6024 and contains 4 outputs IC2a, IC2b, IC2c and IC2d.

IC2a output corresponding to a non-inverting amplifier configuration repeater can be mounted a measuring device or a computer with which we monitor and measure the atmospheric electric field. In particular, analog measuring devices a better picture of atmospheric instability as the system detects a high potential oscillations observed the indicating dial [1,2,9,10].

In figure 2 we present a simple circuit where the emitter potential varies with atmospheric electricity discharge.

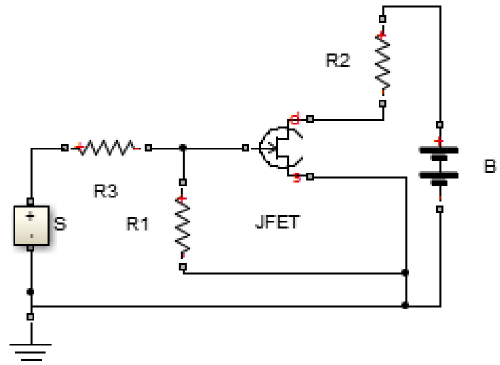

Fig. 2 Circuit for detecting atmospheric electricity

An example to the model in Matlab&Simulink is presented in figure 3.

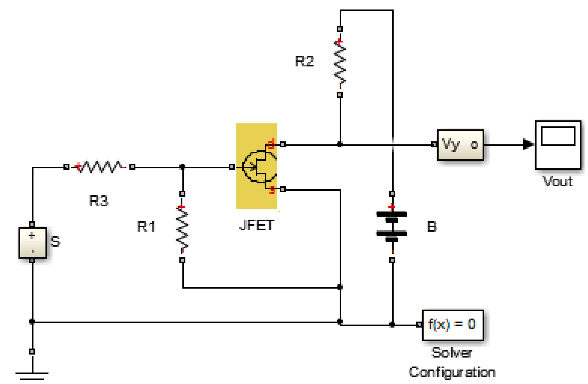

Fig. Model Matlab&Simulink

Results are in figures 4 and 5.

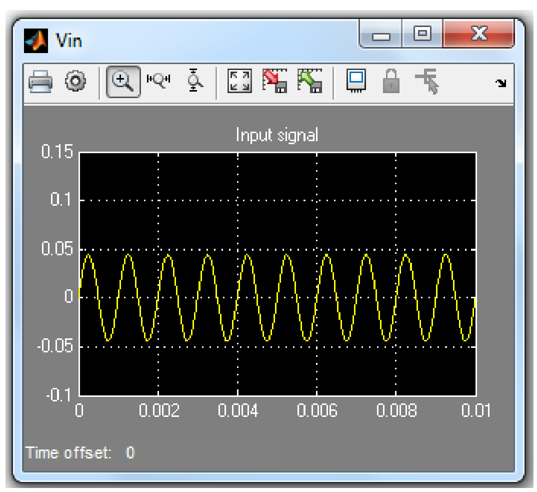

Fig. 4 Input signal for response the system

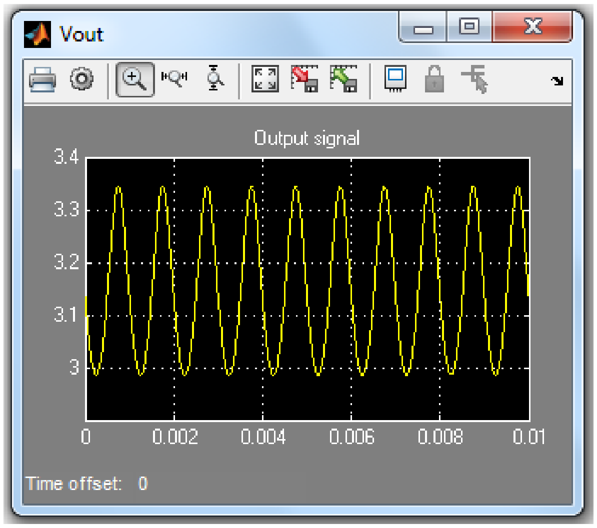

Fig. 5 Response the system - output signal

The electronic scheme for this system is shown in figure 6.

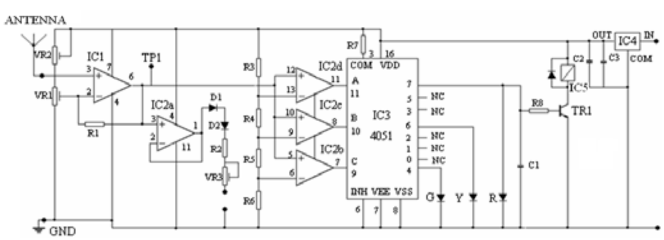

Fig. 6 Electronic scheme for this system

The integrated circuit MCP 6022 is an amplifier "rail to rail" whose role is to command circuit MCP 6024 and is composed of four amplifiers arranged as follows:
- a non-inverting amplifier repeater configuration for impedance matching which is next circuit to the window comparator;
- the comparator, consisting of the remaining amplifiers.

The features of electrical circuits MCP 6022 and MCP 6024 are:
-supply voltage is between 2.5V and 5.5V;
-current input pins + 2mA;
-current output pins + 30mA;
-bandwidth frequency 10MHz;
-the noise is 8.7 nV / Hz;
-input offset voltage, low (500μV);
-temperature between -40˚C and + 80˚C;
Electrical characteristics decoder circuit MMC 4051 are:
- supply voltage is between -0,5V and 20V;
- input voltage is between -0.5V and + 0.5V;
- current input is 10mA;
- temperature range is from -55C˚ to +125C˚.
These features make the above integrated circuits suitable for applications requiring high performance such as environment parameters measurement [11,12].

The purpose of the comparator is to compare the two signal inputs, and the result of the comparison may take two values corresponding to two bits 0 and 1 one be observed that there is no feedback, which means that a small difference between the two inputs, will be amplified with a_0 (open loop gain) that an operational amplifier is 10^4 - 10^6 V. Suppose that the amplifier is fed to a voltage +Vcc and -Vcc (15V). If we take a value of a_0, 10^6 the voltage at the inverting input will exceed the non-inverting input voltage due to the open loop gain, output voltage should be -20V. This is not possible because the negative voltage provide by amplifier is -15V.

The comparison operation will result in three levels of voltage shown in figure 7.

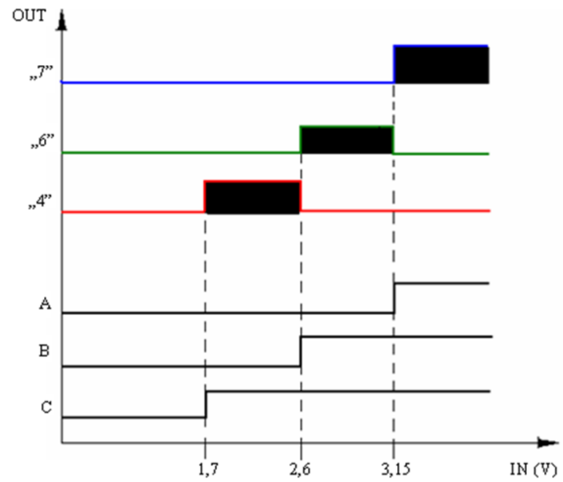

Fig. 7 Three levels of voltage from comparator

Practically the output voltages will be about -15V. We say in this case that the amplifier was saturated "LOW". If the voltage at the non-inverting input will exceed the voltage on the inverting input, the output voltage will be the maximum namely +15V. The levels of tension generated by the comparator system will enter the decoder taking binary values 100, 110, 111.

Table I The truth table for MMC 4051

INPUT				"ON" CHANELS
INHIBIT	A	B	C	
0	0	0	0	0
0	0	0	1	1
0	0	1	0	2
0	0	1	1	3
0	1	0	0	4
0	1	0	1	5
0	1	1	0	6
0	1	1	1	7
1	X	X	X	NONE

The green LED will light at a voltage of 1.7V, the yellow LED will light at a voltage of 2.6V, the red LED will light at a voltage of 3.47V. In conclusion input values 100, 110 and 111 will match the output values 1.7V, 2.6V and 3.47V. Value 111 from pin 4 (7) is used in order to trigger the relay through the transistor TR1 [11].

The capacitors C1 together the resistor R8 forms an RC configuration derivative, also known as a high-pass filter, which is designed to provide pulses in the entry of the transistor TR1. Thus, on this basis, we have a train of pulses shown in figure 8.

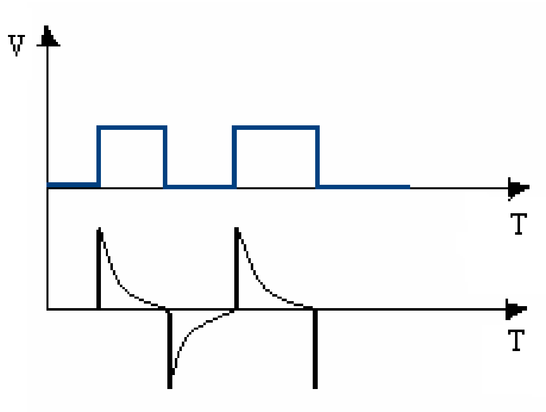

Fig. 8 Pulses for RC configuration derivative

The relay is designed to switch 2A at maximum voltage of 220V DC or 250V AC. In parallel we connect a diode for protection the transistor [12].

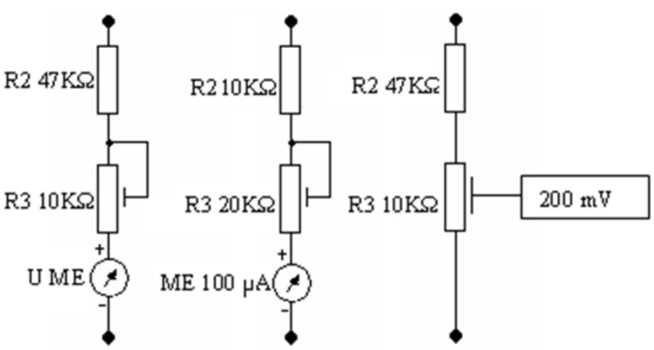

Fig. 9 Scheme of connection of the measuring device

For permanent monitoring atmospheric load is used as the output interface block IC2a from IC2, with the ability to connect a measuring device or a PC (see fig. 9).

The circuit design is based on an analog measuring device to better highlight the atmospheric instability.

Diodes D1 and D2 together with resistors R2 and VR3 will adjust the current through the measuring device which can be an analogical or a digital one.

Table II Automat system's components

Resistors		Variable resistors		Diodes	
R1	2M2	VR1	2MΩ	D1	1N4148
R2	4K7,10KΩ	VR2	500KΩ	D2	LED green(3mm)
R3	270kΩ	VR3	10kΩ,20KΩ	D3	LED green(8mm)
R4	100kΩ			D4	LED yellow(8mm)
R5	180kΩ			D5	LED red(8mm)
R6	330kΩ				
R7	30Ω				
R8	4k7				
Transistors		Integrate circuits		Other components	
TR1	2N3904	IC1	MCP 6022	board PCB	
		IC2	MCP 6024	cable	
		IC3	MMC 4051		
		IC4	LM 7805		
		IC5	Relay		

Immediately below the antenna, a section of the cable is connected to a metal rod and buried in the ground.

The antenna is provided with a 7 tips made of copper rods 1 mm in diameter welded together to base what are sharp peak in order to increase the sensitivity of the antenna [13, 14, 15, 18]. The copper 7 rods each measuring 70 mm from the top to the point where they are glued and form together, at the top, a circle with a diameter of 70 mm. Basically, the rods are glued in the middle of a microphone cable. We chose this type of cable as it provides good protection from interference [19].

A model of the antenna is shown in figures 10 and 11. This model was developed in Matlab&Simulink programming environment [16, 17, 20], using two methods: phased.CustomAntenna Element represented in oxy coordinates and phased.ConformalArray represented in polar coordinates.

This example shows how to can construct a single antenna element. It is declared the azimuth angle and the elevation angles.

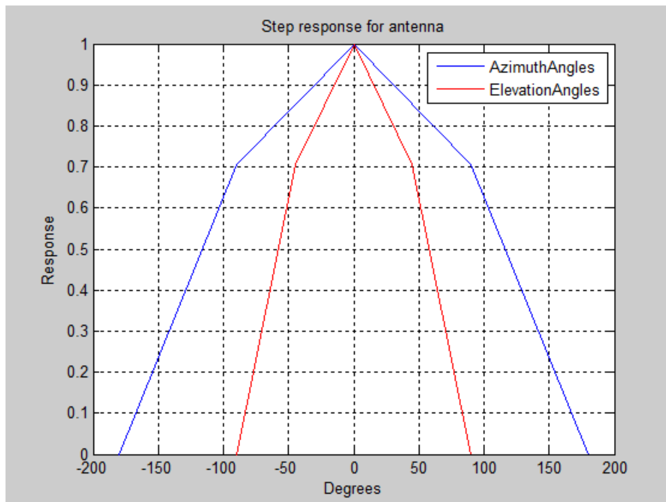

Fig. 10 Phased.CustomAntennaElement method

The resulting matrix is as follows:

$$anten = \begin{bmatrix} 0{,}000 & 0{,}000 & 0{,}000 & 0{,}000 & 0{,}000 \\ 0{,}707 & 0{,}707 & 0{,}707 & 0{,}707 & 0{,}707 \\ 1{,}000 & 1{,}000 & 1{,}000 & 1{,}000 & 1{,}000 \\ 0{,}707 & 0{,}707 & 0{,}707 & 0{,}707 & 0{,}707 \\ 0{,}000 & 0{,}000 & 0{,}000 & 0{,}000 & 0{,}000 \end{bmatrix}$$

And response numeric is: $antresp = \begin{bmatrix} 1{,}000 \\ 1{,}122 \end{bmatrix}$

This example shows how to can construct a uniform circular array consisting of 7 elements (all object of the antenna). The normal direction of the elements is equal to [ang; 0] where ang is the azimuth angle of the array element.

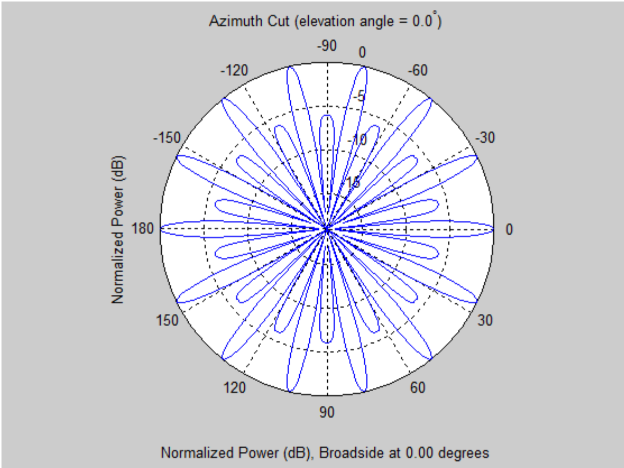

Fig. 11 Response antenna in polar coordinates

Peak with the 15 m antenna cable are placed in a PVC tube, which is fixed to the tube with a plastic clamp. The whole assembly measures 2.2 m and installs two feet from the exterior wall of the building.

III. CALIBRATING THE SYSTEM

If Before powering the circuit will adjust variable resistors VR3 and VR2 follows:

- the cursor VR3 will rotate in anticlockwise direction until it reaches the maximum threshold;
- the cursor VR2 will rotate in a clockwise direction until it reaches the maximum. The next step is to feed the circuit with a voltage between +7V and + 35V.

At this time the red LED should be lit and the relay closed. The voltage at point TP1 should indicate a value 3.47 V. Monitoring the point TP1 voltage the cursor VR2 rotates anticlockwise. At some point the red LED will turn off and the relay will open. At the same time the yellow LED will begin to flash, extinguished at a voltage value 2.6V. Finally the green LED will light at a voltage of 1.7V. After performing calibration, the system will stabilize the value indicated by the green LED. If potential monitoring system is too small the green LED will go out. In these circumstances you will need to rotate the cursor VR2 clockwise until it will lights again.

Under certain atmospheric conditions can alter the sensitivity of the system, changing the resistance value R1 or changing the whole chain of resistors R3 to R6. For example, the red LED lights up 3.47V value, which is equivalent to 5V*(R4+R5+R6)/(R3+ R4+R5 +R6), while the yellow LED will light up at a value 2.9V equivalent to 5V*(R5+R6)/(R3+R4+ R5+R6).

IV. CONCLUSION

The monitoring and warning system built for atmospheric discharges is much more useful and important as a regular lightning conductor. Given that every second, the world take place about 2000 thunderstorms accompanied by thunders and lightning's which is a major risk to all people, they causing more deaths than other natural hazards, including tornadoes and hurricanes, we can say that there are many good reasons to build an automatic monitoring system thunders and timely warning. One of these reasons would be the very low cost of the system and its friendly use interface.

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