Complex system for earthquake prediction and protection of gas installations

Victorin Emilian TOADER[1], Ovidiu CIOGESCU[2], Andrei MIHAI[1], Daniel LNGVAY[2], Adriana BORŞ[3*], Iosif LINGVAY[2]

[1] National Research - Development Institute for Earth Physics INCDFP, Măgurele, Ilfov County, Călugareni street, no. 12
[2] S.C. Electrovâlcea SRL, Râmnicu Vâlcea, jud. Vâlcea, Ferdinand street, no. 19
[3] ICPE SA, 313 Splaiul Unirii, 030138, Bucharest, Romania
(*Correspondence author)

Abstract:
In order to prevent explosions and fires caused by the ignition of uncontrolled gas leaks from damaged pipes following some devastating earthquakes, a complex system for earthquake prediction and protection of gas installations has been designed.
The designed system ensures both the acquisition of data on local precursor parameters (evolution of radon emanations, evolution of earth's crust temperature, etc.) and local intensities of seismic events. Their transmission for processing to the national seismic dispatcher, thus contributing to a better knowledge in the earth physics field and implicitly to increase the accuracy of seismic predictions as well as 3D measurement of the local intensity of tectonic movements. In the case of seismic events with dangerous local intensity (above a pre-imposed, programmable threshold) the control signal is generated for the closure of gases by specialized aquatics (electrovalves mounted in front of the gas regulation / measurement block of the protected buildings).
The system also ensures the take over and display of the information package about the state (closed / open) of the electrovalves mounted in front of the gas regulation / measurement block of the protected buildings. The 3D vibration transducer and the temperature transducer for the data acquisition system are mounted in a 40 m deep drilled well and the radon one on the surface (in the protection and visiting chimney of the well with transducers).
Representative images regarding the realization / implementation of the system are presented.
Compared to the known alert systems, the designed system requires little space for implementation and provides a number of advantages such as: - providing information on the evolution of precursor parameters of seismic movements in a given locality to the national seismic dispatcher, the level of knowledge in the field of Earth physics and the predictability of earthquakes; - local validation of the intensity of tectonic movements in 3D and automatic closing in real time, without human intervention, of the gas connections in case of exceeding a pre-established dangerous threshold; – prevention of explosions and devastating fires following the damage of gas installations due to major earthquakes in a given locality (where the system is implemented), especially in public institutions, schools, boarding schools, hospitals, old people's homes, etc.

Key words: earthquake, precursors, gas networks, fire, explosions, protections

1. Introduction

The aspect regarding the prediction of natural disasters, including earthquakes, is a theoretically complex issue with special material and social implications [1, 2].

Earthquakes are the result of the discharge of energies accumulated by the movement of tectonic plates in the earth's crust.

Energy accumulation speed, reaching the mechanical stresses between the plates where the discharge occurs, etc. are complex phenomena determined by a series of factors and parameters specific to the physics of the Earth.

It follows that earthquakes produced at different depths at the interface / faults between the tectonic plates are difficult to predict. Earthquakes are preceded by a series of changes in some physical parameters in the lithosphere.

Thus, following the increase of the voltages between the tectonic plates, respectively following the energy accumulations, the electrical conductivities of the layers in the lithosphere change [1].

Under these conditions, changes recording following continuous monitoring of the electrical conductivity of the lithosphere layers may provide indications of the imminence of earthquakes.

On the other hand, energy accumulations and changes in mechanical stresses in the lithosphere produce changes in the permeability for radon (Rn) and CO_2 of rocks [3], radon and CO_2 emissions being the precursor parameters of earthquakes [1, 3 - 11].

In the case of major earthquakes, the damage to gas networks [1] occurs frequently. The pipelines and/or fittings of both polyethylene and polypropylene [12, 13] often break because the polymeric materials are affected by exposure to soil factors, aging accelerators such as mechanical stress, microbiological activity, etc. [14-16].

The metallic ones [13, 17] are affected by various forms of corrosion [16 - 19]. As a result of uncontrolled gas leaks from gas networks affected by earthquakes, devastating explosions and fires frequently occur with consequences such as human casualties, material damage, major impact on the environment, etc.

In the perspective of sustainable development, ensuring safe and acceptable working and living conditions in a healthy environment is a complex issue with great material and/or social implications [20 - 22] which also includes the aspect of preventing environmental pollution (with anthropogenic pollutants or/and of natural origin due to natural disasters).

In this context, the purpose of the paper consists in the conception and realization/implementation in the municipality of Râmnicu Vâlcea of a complex system for earthquake prediction and protection of gas installations.

2. System design

The previous study [1] defined the main characteristics and performances that must be met by a complex earthquake prediction system and ensure the protection of gas installations in a given perimeter / locality, respectively:

- Acquisition of precursor data to earthquakes in the given locality and their transmission for processing to the national seismic dispatcher;
- measurement / validation of the intensity of local tectonic movements (in 3D);
- generation of control signal which ensures the shutdown (automatic, real time and without human intervention) of gases at the connections of buildings connected to the system, only if the intensity of seismic movements in the locality exceeds a required level (considered dangerous);
- secure digital communication - with autonomous UPS power supply, between the place of measuring / evaluating the intensity of local seismic movements and the execution equators (electrovalves mounted in front of the gas regulation / measurement block of the protected buildings).

Based on these considerations, was designed a complex system for earthquake prediction and protection of gas installations which schematically shown in Figure 1 [23].

The designed system (Figure 1) is configured around a national seismic dispatcher (DSN) in which both the data of the precursor parameters and characteristics (epicentre location, depth, intensity, etc.) of the entire monitored territory are stored and processed.

The national seismic dispatcher (DSN) is connected to a computerized local / zonal dispatcher (DL) through a special telecommunications system that permanently ensures the exchange of data (data packets P1 and P2 respectively) between DSN and DL.

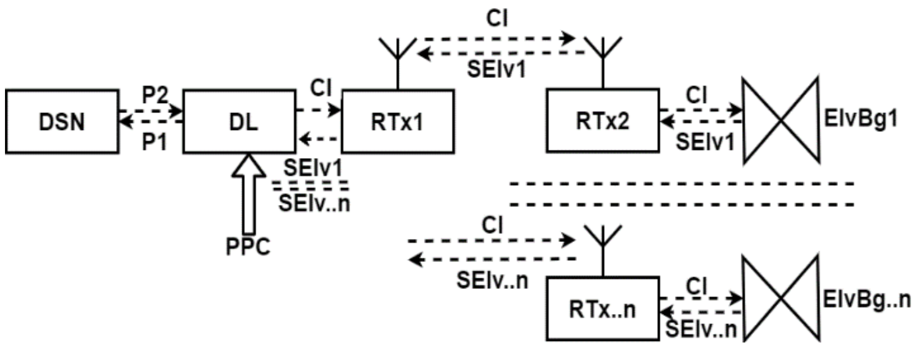

Figure 1. Outline of the complex system for earthquake prediction and protection of gas installations [23]

The local **DL** dispatcher has multiple functions, respectively:

- the acquisition of data regarding both the local precursor parameters (the evolution of radon emanations, the evolution of the earth's crust temperature, etc.) and the local intensity of seismic events - **PPC**. Transmission of locally acquired data **P1** to **DSN** for processing (thus contributing to a better knowledge in the field of earth physics and also, to increasing the accuracy of seismic predictions);
- in order to alert, take over and process the **P2** information transmitted by **DSN** regarding the imminence of seismic events;
- in case of seismic events with dangerous local intensity (above a pre-imposed, programmable threshold) a command signal is generated for closing **CI** of the gases through specialized aquatics (electrovalves **ElvGg1 - ElvBg ...n** mounted in front of the gas regulation / measurement block of protected buildings);
- downloading and displaying the closed / open status information package (**SElv1…. SElv..n**) of electrovalves mounted in front of the gas regulation / measurement block of the protected buildings.

Ensuring secure communications (functional in real time even after major seismic events - when GSM networks are frequently inaccessible, the electricity network is interrupted, etc.) between the local dispatcher (**DL**) and the protected buildings in that locality is a complex issue, a real technical-economic challenge.

Transmission of the control CI signal for gas shut-off by **ElvGg1 - ElvBg… n** electrovalves generated by **DL** (only in case of major seismic movements, considered dangerous as a result of local measurement and validation of seismic vibration amplitude in 3D - **PPC** data package) is provided by configured telecommunications system. This system includes the **RTx1** reception emission station (connected directly to the local **DL** dispatcher computer) and the **RTx2 - RTx..n** reception emission stations installed next to the electrovalves **ElvGg1 - ElvBg ...n** mounted in front of the gas regulation / measurement block of the protected buildings from that locality.

The telecommunications network consisting of RTx1 and **RTx2 - RTx..n** include low power transmitting-receiving stations (up to 20 W), stations which are provided with properly sized antennas to ensure (within a radius of about 25 km) the transmission / reception in digital working mode (thus avoiding possible undesired disturbances / interferences) of the **CI** or **SElv1…SElv..n** information packets.

All electrical consumers of the system outlined in figure 1 (**DSN** calculation system, computerized **DL**, **PPC** data acquisition system, **RTx1** and **RTx2 - RTx..n** transmitting-receiving stations and electrovalves **ElvGg1 - ElvBg… n**) are provided with power autonomous supply (UPS) which ensures the operation even after power failure (frequent phenomenon in major earthquakes) on electrical networks (power lines).

In view of these aspects, it can be seen that the complex system for earthquake prediction and protection of gas installations outlined in Figure 1 has a number of advantages, such as:

- low electricity consumption;
- ensures the provision of information on the evolution of the precursor parameters of seismic movements from a given locality to the national seismic dispatcher, data that by processing which the level of knowledge increases in the field of Earth physics - including earthquake predictability;
- ensures the local validation of the intensity of tectonic movements in 3D and the automatic closing in real time, without human intervention, of the gas connections in case of exceeding a predetermined dangerous threshold;
- validation / confirmation of the closed / open state of the electrovalves through a bilateral system of communication between the local dispatcher and the electrovalves for gas connections of the system;
- ensures the prevention of explosions and devastating fires following the damage of gas installations due to major earthquakes in a given locality (where the system is implemented), especially for public institutions, schools, boarding schools, hospitals, nursing homes, etc.;
- requires little space for implementation.

3. Precursor data acquisition system and 3D measurement of local seismic intensity (PPC)

Earthquake prediction is a complex issue and is based on the acquisition of data from the territory and the processing of precursor parameters such as: the electrical conductivity evolution of the lithosphere layers, the evolution of radon emanations [3-11], anomalies in propagation of the radio waves [24-27], the deepwater level variations [9], the soil temperature evolution [5,8,10] etc. The predictions accuracy is determined by the volume of data packets purchased and how they are processed.

In this context, the system outlined in Figure 1 is provided with a set of sensors and transducers which ensures the acquisition of data on the one hand on the evolution of precursor parameters (radon detector type Radon Scout Plus manufactured by SARAD GmbH - Germany and transducer temperature type PT100) and on the other hand the local amplitude of tectonic movements (3D vibration transducer type HYPOSENSOR FBA ES-DH manufactured by Kinemetrics - USA connected to the system through a digitizer type K2 - Kinemetrics).

The location sketch of the transducers is illustrated in Figure 2 [23].

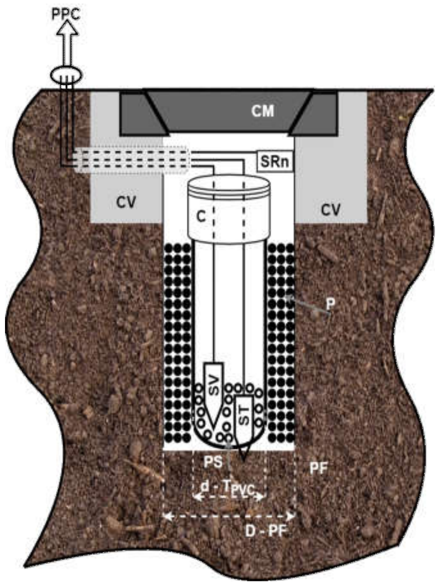

Figure 2. The location sketch of the transducers [23]

According to figure 2, the vibration transducer **SV** is mounted between glas beads **PS** in a drilled well **PF** 40 m deep and **D-PF** diameter Φ 350 mm. For the **SV** protection and of the **ST** temperature sensor, they are mounted in a PVC protection tube with a diameter of **d-T**$_{PVC}$ Φ 120 mm. The space between the **T**$_{PVC}$ and the diameter of the drilled well **D-PF** is filled with gravel **P** (1-3 cm) which ensures the diffusion of radon to the radon detector **SRn** mounted in the manhole **CV** made of reinforced concrete and covered with a metal cover **CM**.

The PVC **T**$_{PVC}$ protection tube is covered with a **C** cover also made of PVC. Representative images regarding the construction in Râmnicu Vâlcea town of a precursor data acquisition system and the local intensity measurement of seismic movements.

Figure 3 shows the installation with which the drilling was performed and the PVC $\mathbf{T_{PVC}}$ protection tube was mounted.

Figure 3. Drilling rig - T_{PVC} mounting

The installation of the seismic vibration detection system is performed with the help of the mobile auto-laboratory equipped with verification and calibration devices at the ground surface (before launching in TPVC) of the vibration transducer coupled with the K2 type digitizer.

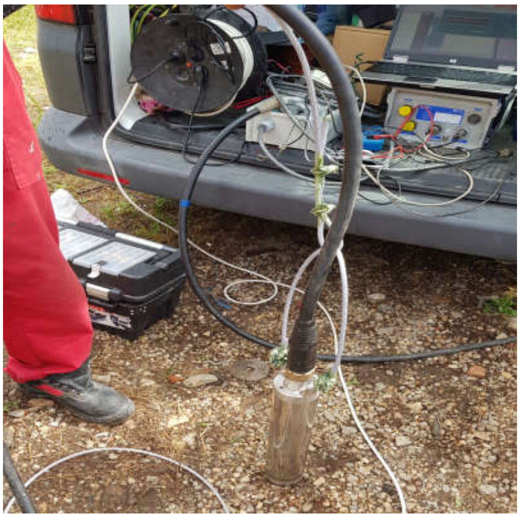

Figure 4. Checking / calibrating the 3D vibration detector - coupling with digitizer K2

Figure 4 shows the mobile auto-laboratory for mounting the verification / calibration system and monitoring on the ground surface of seismic vibrations with the 3D vibration transducer used type HYPOSENSOR FBA ES-DH - Kinemetrics oriented in the north-south direction (before launch in TPVC) a vibration transducer coupled with K2 type digitizer.

A system for acquiring precursor data and measuring the local intensity of seismic movements (developed at Râmnicu Vâlcea) was used to detect seismic vibrations in identified sensitive areas.

The installation of such a system requires equipment and measuring apparatus adaptable to such areas. Vibration displacement measurement involves optical measurement techniques, contact-based sensors, electromagnetic or capacitive displacement sensors but also sensors based on acceleration integration. Seismic vibrations are low frequency below 10 Hz and amplitudes can be very small, even if the acceleration is high. Inductive or capacitive displacement sensors have a very good resolution of the order of ***ɥm*** so they can detect small displacements. Vibration transducers have integrated signal conditioners and transform vibrations into electrical sizes in the form of voltage or current so that they can be transmitted remotely. From each area where the sensors are placed, all the data transmitted by them are stored and centralized. The central data processing system collects all the data from all the recording areas and can provide information about the direction of propagation and the amplitude of the seismic waves so that a map can be made with these waves. Measuring the voltage generated by the sensors requires attention to the dynamic behaviour of the signal cable and the input characteristics of the operational amplifier. The capacity of the connecting cable directly affects the amplitude of the signal and during the measurement, it can determine variations of its capacity which must be avoided. As such, connecting cables of different lengths can be used without the need for recalibration. However, the dynamic range of the output voltage is affected by the supply voltage. At large variations of the supply current, problems can occur at the frequency response, when loads with high electrical capacity occur.

The information (data and images) recorded locally, synchronized are stored and transmitted to the national seismic dispatcher for processing, interpretation, and realization of the seismic map with risk areas.

The electronic display of the device from the endowment of the mobile auto-laboratory registers with the help of the vibration transducer their intensity.

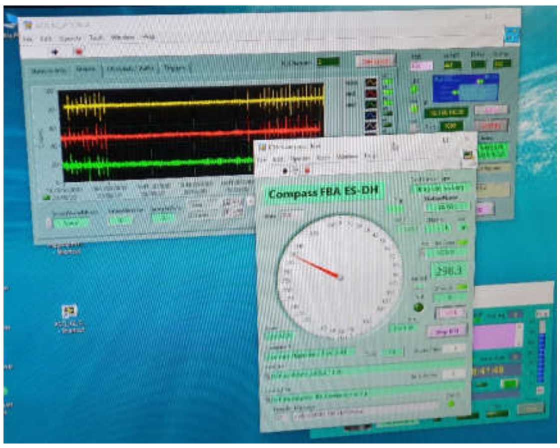

Figure 5. Calibration and orientation diagram of the vibration transducer recorded with the mobile auto-laboratory

For the purpose of good stabilization at the bottom of the well, the vibration detector was placed in a bed of glas beads Φ 4 mm made by MARIENFELD - Czech Republic (Figure 6).

Figure 6. Pouring a bed of glas beads into the protective tube T_{PVC}

The launch of the vibration transducer in the T_{PVC} protection tube is shows in Figure 7.

Figure 7. Launch the 3D vibration transducer into the protection tube

When launching the transducer, its orientation according to the GPS compass of the transducer in the north-south direction was taken into account.

After placing the transducer in the wellbore, 5 kg of glas beads were inserted to completely cover it.

Radon released from the soil is present throughout the year, but its level varies depending on weather, season, and other factors. There are a number of variables for which radon levels change substantially and with high frequency, thus requiring emissions monitoring. Radon is a colorless, odorless, radioactive gas that is all around us, in the air we breathe, it is part of the natural background of the radioactivity of so it is important to know its level to breathe quietly.

The radon level recommended by the World Health Organization for reducing potentially harmful effects is 100 Bq/m^3 (Becquerel is a unit of measurement of radioactivity), while the national reference level is set at 300 Bq/m^3.

Figure 8. Radon detector (SARAD-Germany)

Figure 8 shows the SRn radon detector mounted in the manhole (CV). The transmission of the measured PPC parameters from the manhole to the computer of the local dispatcher (DL) is performed with suitable signal cables laid in a wiring channel.

4. Conclusions

In order to prevent explosions and fires caused by the ignition of uncontrolled gas leaks from damaged pipes following devastating earthquakes, a complex system for earthquake prediction and protection of gas installations has been designed.

The designed system ensures:

— the acquisition of data regarding both the local precursor parameters (evolution of radon emanations, evolution of the earth's crust temperature, etc.) and the local intensity of seismic events and transmission for processing and analysis to the national seismic dispatcher. The system thus contributes to a better knowledge in the field of earth physics and implicitly to the accuracy increase of seismic predictions;

— in case of seismic events with dangerous local intensity (above a pre-imposed, programmable threshold) the system allows 3D measurement of the local intensity of tectonic movements. A signal is generated for the command to close the gases through specialized aquatics;

— taking over and displaying the information package regarding the closed / open condition of electrovalves mounted in front of the gas regulation / measurement block of the protected buildings.

The data acquisition system includes a 3D vibration transducer and a temperature transducer which are mounted in a 40 m deep drilled well. On the surface, the radon transducer is mounted in visiting and protection chimney of the well.

Compared to known alert systems, the designed system (under construction / implementation) has a number of advantages, such as:

— low electricity consumption and a small space for implementation;

— ensures the provision of information to the national seismic dispatcher (DSN) regarding the precursor parameters evolutions of the seismic movements in a given locality, for better predictability of the earthquakes;

— ensures the local validation of the intensity of tectonic movements in 3D and the automatic closing in real time of the electrovalves;

— ensures a good bilateral communication between the local dispatcher and the electrovalves of the gas connections connected to the system in case of exceeding a predetermined dangerous threshold;

— in case of damage to gas use installations as a result of a major earthquake, it ensures the prevention of explosions and devastating fires in a given locality for those public institutions, schools, boarding schools, hospitals, old people's homes, etc., where the system is implemented;

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8. Authors' Biographies

Dr. eng. Victorin Emilian TOADER, senior researcher in National Institute for Earth Physics (National Seismic Network Department), graduated University of Bucharest, Faculty of Electronics and Telecommunications. He is PhD in Physics with thesis title "Vrancea tectonic stress analysis through electromagnetic methods and associated factors for the purpose of achieve a seismic forecast". He has experience in hardware and software: data acquisition and analysis, research seismic and pre-seismic signals, seismic event detection, analysis of radon, solar radiation, and air ionization. He designed and elaborated networks for seismic application (EWS and earthquake forecast). He is the author of several patents like "Complex seismic warning equipment of industrial objectives with local decision and confirmation, a 2017 00744 / 27.09.2017, OSIM RO-BOPI 3/2019".

Professional e-*mail:* victorin@infp.ro

Dr. eng. Ovidiu CIOGESCU was born in Budesti – Valcea (RO) on September 18, 1961. He graduated the University "Politehnica" of Bucharest (RO) in 1986. Between 1986 – 1993 he worked as an engineer at the Electronic Components Research Institute. He became PhD in Electrical Engineering- ISCED 6– (Post-graduate doctoral studies)in 2012. He is researcher in electrical engineering at SC Electrovalcea SRL - Râmnicu Vâlcea - RO.

Professional e-mail: electrovalcea@yahoo.com

Mr. Andrei MIHAI - graduated from the Faculty of Geology and Geophysics, Bucharest University and obtained the geologist engineer diploma. Now he is a Ph.D. student in the field of Earth Physics. His Ph.D. dissertation title: "*Correlations between local geo-magnetic field and the seismicity of Vrancea zone*". He is scientific researcher, with more than two years of experience in the earth sciences research at National Institute for Earth Physics (Romania). Involved in processing the magnetic data and also other types of data: seismic, meteorological, satellite data. His main research domain includes geomagnetism, seismology and tectonics.

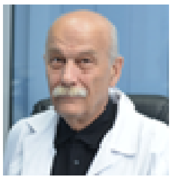
Professional e-mail: asyst@asystech.ro

Eng. Daniel LINGVAY was born in Bucharest (RO), on Nov. 29, 1994. He finished his BSc studies at the "Babes-Bolyai" University in Cluj - Faculty of Physics specializing on physics- informatics. He is graduate of MSc at Technical University of Cluj - Special Applications in Integrated Communication Systems. He is currently developing Eng. at S.C. Electrovâlcea SRL from Râmnicu Vâlcea - RO. He is interested in electrical measurements, EMC and radio communications – is a licensed ham radio with call sign YO5LD since 2009, and he is "Master of Sports" since 2012.

Professional e-*mail:* daniel_lingvay@yahoo.com

PhD. Chem. Adriana Mariana BORȘ was born in Alexandria (Romania), on July 6, 1975. She graduated the University of Bucharest, Faculty of Chemistry, Section "Chemical Technology and Catalysis (Romania), in 1998. She received the PhD degree in chemistry from the University of Bucharest, in 2007. She is senior researcher at ICPE Bucharest. Within the Electro Technical Research Institute, her research interests concern: analytical chemistry, industrial pollution control, dispersion of pollutants, fluid mechanics, mechanisms for determining critical loads and atmospheric pollutants

Professional *e-mail*: adrianambors@gmail.com



Dr. eng. Iosif LINGVAY was born in Sighetu Marmației (RO), on February 25, 1949. He graduated the University „Politehnica" of Bucharest, (RO) in 1972 and in 1984 received the PhD degree in electro-chemistry. He is senior researcher CS I, scientific advisor at SC. ICPE Bistrița SA (in Bistrița - RO) and SC. Electrovâlcea SRL (in Râmnicu Vâlcea - RO). Between 2002 and 2019 had been scientific secretary at INCDIE ICPE-CA in Bucharest - RO. He won the "Denis Gábor" prize in 2017 for science and innovations. His research interests concern in study and control of corrosion, materials, operating safety of underground pipelines and cables, marine corrosion, insulating oils, operating safety of transformers, bio EMC, energy save etc.

Professional e-*mail*: coroziune@icpe-ca.ro