Framework of Cloud Based Learning System for Risk Analysis of the Bulgarian Electricity Network under Natural Hazards

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Abstract: In recent years worldwide are observed an increase in the negative effects of natural hazards on critical infrastructure, as well as on the Bulgarian electricity network. The aim this paper is to propose a framework of cloud based learning system for risk analysis of the Bulgarian electricity transmission and distribution network under natural hazards. The learning system includes several components: lists with monitored objects and predominant natural hazards on Bulgarian territory with their characteristics and locations in GIS; potential impacts caused by the natural disasters described; quantitative and qualitative methods for risk analysis and assessment of risk levels. The risk analysis results obtained with the proposed learning system can support the all stakeholders to take more informed decision about effective protection of the electricity network from natural hazards. The power outages strongly affect the transmission of data in Web and as well the all activities on the Internet as e-Education, e-Business, e-Management, e-Learning.

Key words: Bulgarian electricity network, interactive training system, natural hazards, risk analysis.

1. Introduction

Nowadays, worldwide are observed an increase in the negative effects of natural hazards on the energy systems [1]. The number and duration of temporary power breakouts are enlarged [2]. The Bulgarian electricity transmission and distribution network is also heavily affected [3].

The impact of natural hazards on the electricity network can be direct and indirect. The direct impact can be seen as damages to monitored objects. However, it is more important to take into account the indirect impact that is associated with the power outages which affected on the business continuity [4], [5].

The electricity has now become a vital part of modern societies. The electrical equipment is involved in every aspect of people's lives and business. Therefore, the power outage severely disturbs the normal course of daily activities [6], [7]. The modern economies and societies can properly function only with continuous power supply. For this reason, the importance of the management's awareness of the potential risks of power outages due to the occurrence of natural disasters has increased. [8], [9].

The power outages strongly affect the transmission of data in Web and as well the all activities on the Internet as e-education, e-business, e-management, e-learning, etc.

The aim this paper is to propose a framework of cloud based learning system for risk analysis of the

Bulgarian electricity transmission and distribution network under natural hazards. The learning system includes several components: lists with monitored objects and predominant natural hazards on Bulgarian territory with their characteristics and locations in GIS; potential impacts caused by the natural disasters described; quantitative and qualitative methods for risk analysis and assessment of risk levels

2. Problem Statement

In this study, the risk assessment is considered as part of the overall risk management process according to basic standards: ISO 31000:2009 "Risk management — Principles and guidelines" and IEC/ISO 31010:2009 "Risk management - Risk assessment techniques". The risk assessment includes risk identification, risk analysis and risk evaluation.

Here, for the purpose of risk analysis of Bulgarian electricity network under natural hazards the following term definitions are used [10], [11]:

- *Natural hazard*: Natural process or phenomenon that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage. Natural hazard events can be characterized by their magnitude or intensity, speed of onset, duration, and area of extent.
- *Hazard assessments* determine the probability of occurrence of a certain hazard of certain intensity.
- *Risk* is a combination of the consequences of an event (*Hazard*) and the associated likelihood/probability of its occurrence.
- *Risk assessment* is the overall process of risk identification, risk analysis, and risk evaluation.
- *Risk identification* is the process of finding, recognizing and describing risks.
- *Risk analysis* is the process to comprehend the nature of risk and to determine the level of risk.
- *Risk evaluation* is the process of comparing the results of risk analysis with risk criteria to determine whether the risk and/or its magnitude is acceptable or tolerable.
- *Consequences* are the negative effects of a disaster expressed in terms of human impacts, economic and environmental impacts, and political/social impacts.
- *Single-risk assessments* determine the singular risk (i.e. likelihood and consequences) of one particular hazard (e.g. flood) or one particular type of hazard (e.g. flooding) occurring in a particular geographic area during a given period of time.
- *Multi-risk assessments* determine the total risk from several hazards either occurring at the same time or shortly following each other, because they are dependent from one another or because they are caused by the same triggering event or hazard; or merely threatening the same elements at risk (vulnerable/ exposed elements) without chronological coincidence.

According IEC/ISO 31010:2009 [9] in situations where the likelihood of occurrence of a hazard of certain intensity can be quantified investigators refer to the term probability of occurrence. When the extent of the impacts is independent of the probability of occurrence of the hazard, which is often the case for purely natural hazards, such as earthquakes or storms, risk can be expressed algebraically as:

$$Risk = probability\ of\ occurrence * hazard\ impact$$

or

$$R = \mathrm{F}(p\,, C) \qquad \text{or} \qquad R = p * C, \tag{1}$$

where R is risk; P - probability of occurrence of the natural hazard; C – consequences (natural hazard impact).

The proposed framework of the cloud based learning system for risk analysis of Bulgarian electricity network under natural hazards includes several components. The components implement interaction with

Geographical information system (GIS) and heterogeneous databases.

3. Main Components of the Cloud Based Learning System for Risk Analysis

The *first component* of the proposed learning system for risk analysis of Bulgarian electricity network under natural hazards is the list of the monitored objects with their characteristics and locations in GIS. These monitored objects are elements of the electricity transmission and distribution infrastructure.

The *second component* of the cloud based learning system for risk analysis is the list of natural hazards, whose negative impact on Bulgarian electricity network are investigated.

The predominant natural hazards on Bulgarian territory are identified as follows:

- Geological processes and phenomena: Earthquakes; Slope failures (landslides, landslips, creep, falls, flows, subsidence); Mud-rock flows (seli); Erosion and abrasion; Storm surge.
- Hydrological processes and phenomena: Floods; Dry periods; Snow flows and glaciations; Icings.
- Meteorological processes and phenomena: Strong wind; Extreme temperatures; Freezings, Drought, Tornado phenomena; Dust storms; Hailstorms; Wet snow; Fog (coastal, evaporation, radiation, valley, upslope); Thunderstorm; Silver thaw; Wild land fire.

The *third component* of the proposed learning system for risk analysis is list of potential consequences (natural hazard impact) caused by described natural hazards in the second component.

It can be pointed some representative examples of identified risks from natural disasters for the Bulgarian electricity network as follows

- Losses from transmission of electricity due to extremely high temperatures (including hot days and heat waves).
- Damage to the electricity transmission and distribution network from icing due to extremely low temperatures (including cold days and cold airwaves).
- Flooding of the electricity transmission and distribution network (including electricity substations) leading to power breakouts and/or higher capital costs for equipment repairs due to more rainfall and high humidity.
- Droughts that cause soil downgrades, damaging underground electricity transmission and distribution network
- Strong winds and storms damage the electricity transmission and distribution network (for example, from fallen trees), leading to power breakouts and/or higher capital costs for repairs of the equipment.
- Landslides also damage the electricity transmission and distribution network, resulting in power breakouts and/or higher capital costs for equipment repairs.
- The power lines could exceed the established maximum temperatures in the technical documentation and violate the requirement for a minimum distance from the earth's surface due to thermal expansion, which could lead to a power breakout.

In addition, other types of consequences can also be formulated depending on the monitored object, the natural hazards, the specific tasks of the risk analysis of the Bulgarian electricity transmission and distribution network under natural hazards etc.

4. Determination of Risk Level for Electricity Network Objects under Natural Hazards

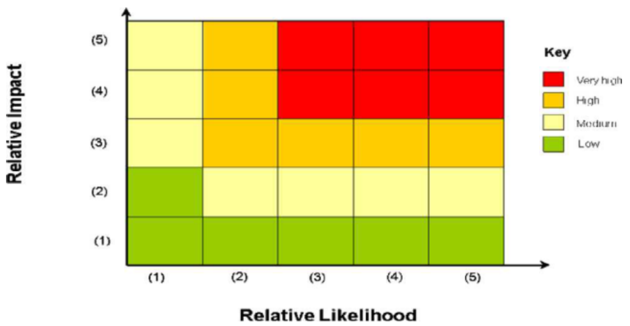
The *fourth component* of the learning system determinates the risk level for monitored object on based the risk matrix. The risk matrix or so-called consequence/ probability matrix is a means of combining qualitative or semi-quantitative ratings of consequence and probability to produce a level of risk.

The format of the risk matrix depends on the context in which it is used. The scale used may have 5 or more points. The matrix may be set up to give extra weight to the impact or to the likelihood, or it may be symmetrical [10].

Usually in risk analysis as part of the risk assessment, the risk matrix 5x5 is used (Fig. 1) as follows:

- *Probability* (Relative likelihood), *p* is graded as "*Very low*", "*Low*", "*Medium*", "*High*" and "*Very high*".
- *Consequences* (Relative impact) are also graded as "*Very low*", "*Low*", "*Medium*", "*High*" and "*Very high*".
- *Risk levels*, *R* are defined as "*Low*", "*Medium*", "*High*" and "*Very high*".

Risk matrix is very helpful in the risk analysis. In particular, the risk matrix or so-called consequence/ probability matrix is a means of combining qualitative or semi-quantitative ratings of consequence and probability to produce a level of risk.



or

Consequences (Relative impact)	Probability (Relative likelihood)				
	(1)	(2)	(3)	(4)	(5)
(5)	*R=2*	*R=3*	*R=4*	*R=4*	*R=4*
(4)	*R=2*	*R=3*	*R=4*	*R=4*	*R=4*
(3)	*R=2*	*R=3*	*R=3*	*R=3*	*R=3*
(2)	*R=1*	*R=2*	*R=2*	*R=2*	*R=2*
(1)	*R=1*	*R=1*	*R=1*	*R=1*	*R=1*

Fig. 1. Risk matrix 5x5: Consequences (relative impact) / probability (relative likelihood).

In this study, it is considered that the natural hazard that causes the corresponding natural disaster has four levels of intensity. Furthermore it is necessary to note that the adequate risk analysis requires producing distinct risk matrices for each severity levels of the natural hazard. Usually it is considered the following four relative severity of the natural hazards: (1) Low hazard severity, (2) Medium hazard severity, (3) High hazard severity, (4) Very high hazard severity (Table 1).

In this case, the risk level is defined as follow:

$$R_{H}^{i} = R_{1H}^{i} + R_{2H}^{i} + R_{3H}^{i} + R_{4H}^{i} \qquad (2)$$

where R_H^i is the risk level caused by natural hazard H^i, i=1, ..., n; R_k is the determined risk corresponding to k severity level of natural hazard H^i, k=1,...,4.

The risk R_k is obtained by following product

$$R_{kH}^{i} = p_k^i \, . \, C_k^i , \qquad k=1, ..., 4 \qquad (3)$$

where p_k^i is the occurrence probability of the natural hazard H^i with k severity level; C_k^i is the consequences caused by action of the of the natural hazard H^i with k severity level.

The calculated value of consequences C_k^i and the given value of the probability p_k^i for occurrence of the natural hazard with k severity level in the considered time interval are substituted in (2) to calculated corresponding risk level R_{kH}^i. Than using (2) it is calculated the total risk assessment R_H^i of the monitored object from the natural disasters in a given geographic region from natural hazard with four severity levels for a certain time interval. Each of the resulting risk levels R_H^i and R_{kH}^i, k=1,...,4 can be presented as a separate risk matrix as the proposed on Fig. 1.

The criteria that characterize each of the five probability levels and consequences, as well as the four levels of risk, according to the features of the elements of the electricity network, are pre-defined.

It is necessary to introduce a complex level of risk that takes into account the impacts of all potential hazards affecting the monitored object. It can be expressed as the sum of the levels of risk associated with these potential hazards as follow:

$$R = R_{H}^{1} + R_{H}^{2} + \ldots + R_{H}^{i} + \ldots + R_{H}^{n}\,, \tag{4}$$

where R is the complex risk level; H^i, i=1, ..., n are potential natural hazard, affecting the monitored object.

The stakeholders can determine the complex risk level for each monitored object of the Bulgarian electricity transmission and distribution network under natural hazards with different severity using proposed cloud based learning system. In particular, Table 1 can be used to determine the complex level of risk according to the severity of several natural hazards. The company management, when dealing with the level of risk, can more effectively manage the risk and reduce the damage, including the indirect losses associated with the interruption of the Internet.

Table 1. Determination of the Complex Risk Level According to the Severity of Several Natural Hazards

Natural hazard H^i	R_1			R_2			R_3			R_4			R_H^i
	p_1	C_1	R_{1H}^i	p_2	C_2	R_{2H}^i	p_3	C_3	R_{3H}^i	p_4	C_4	R_{4H}^i	
H^1	p_1^1	C_1^1	R_{1H}^1	p_2^1	C_2^1	R_{2H}^1	p_3^1	C_3^1	R_{3H}^1	p_4^1	C_4^1	R_{4H}^1	R_H^1
H^2	p_1^2	C_1^2	R_{1H}^2	p_2^2	C_2^2	R_{2H}^2	p_3^2	C_3^2	R_{3H}^2	p_4^2	C_4^2	R_{4H}^2	R_H^2
...													
H^i	p_1^i	C_1^i	R_{1H}^i	p_2^i	C_2^i	R_{2H}^i	p_3^i	C_3^i	R_{3H}^i	p_4^i	C_4^i	R_{4H}^i	R_H^i
...													
H^n	p_1^n	C_1^n	R_{1H}^n	p_2^n	C_2^n	R_{2H}^n	p_3^n	C_3^n	R_{3H}^n	p_4^n	C_4^n	R_{4H}^n	R_H^n
Complex risk level of the monitored object													$\boldsymbol{R}$

5. Quantitative Determination of Risk Level for Electricity Network Objects under Natural Hazards

Numerous simulation experiments were conducted with different values of the input variables (the probabilities and consequences of the considered natural hazards) to determine the risk level of the monitored object. The simulations were carried out with different number of potential natural hazards.

The simulation results for two monitored objects, affected from specific natural hazards are shown in Tables 2-3. The different values for the complex risk level for the both monitored objects (*I* and *II*) are determined using (2)-(4). It is assumed that the first monitored object (*I*) is primarily affected by five natural hazards and the second monitored object (*II*)- by four disasters.

In this study, it is assumed that there is no mutual influence between disasters.

As inputs for the fourth component of the system, different values are given for the relative probabilities and consequences. The specific values for the relative probabilities and consequences are determined on the base of past event statistics, probability calculations and expert knowledge.

Table 2. Determination of the Complex Risk Level of the Monitored Object *I* According to the Severity of Five Natural Hazards

Natural hazard H^i	R_1			R_2			R_3			R_4			R_H^i
	p_1	C_1	R_{1H}^i	p_2	C_2	R_{2H}^i	p_3	C_3	R_{3H}^i	p_4	C_4	R_{4H}^i	
Earthquakes - H^1	(3)	(1)	3	(2)	(2)	4	(1)	(3)	3	(1)	(4)	4	14
Landslides - H^2	(5)	(1)	5	(4)	(2)	8	(3)	(3)	9	(2)	(3)	6	28
Strong wind - H^3	(5)	(2)	10	(5)	(2)	10	(4)	(3)	12	(3)	(4)	12	44
High temperatures - H^4	(4)	(1)	4	(4)	(2)	8	(3)	(2)	6	(4)	(3)	12	30
Floods - H^5	(4)	(1)	4	(3)	(1)	3	(2)	(2)	4	(1)	(3)	3	14
Complex risk level of the monitored object													***130***

Table 3. Determination of the Complex Risk Level of the Monitored Object *II* According to the Severity of Four Natural Hazards

Natural hazard H^i	R_1			R_2			R_3			R_4			R_H^i
	p_1	C_1	R_{1H}^i	p_2	C_2	R_{2H}^i	p_3	C_3	R_{3H}^i	p_4	C_4	R_{4H}^i	
Earthquakes - H^1	(4)	(1)	4	(3)	(2)	6	(2)	(3)	6	(1)	(5)	5	21
Mud-rock flows – H^2	(4)	(1)	4	(4)	(2)	8	(3)	(2)	6	(4)	(3)	12	30
Strong wind - H^3	(5)	(2)	10	(5)	(2)	10	(4)	(3)	12	(3)	(4)	12	44
Freezings – H^4	(3)	(1)	3	(3)	(2)	6	(2)	(3)	6	(2)	(4)	8	23
Complex risk level of the monitored object													***118***

The results obtained for the complex risk level indicate that the first object is more risky than the second one in respect to the considered natural hazards. Therefore, stakeholders have to take decisions related to the reduction of the risk level for the first monitored object.

6. Cloud Based Framework Implementation

The discussed framework is proposed to be implemented as a cloud based learning system. Some principles should be applied to this architecture and its functionality [12]:

- Learning content - Content needs to be presented in various different forms and mediums from dynamic conversation-based streams to well thought-out narratives and information visualization dashboards.
- Learning locations - Learning should take place in different locations during the day. Material under study would connect with the objects in the environment.
- Storage of learning content - Content will be organized in an associative way through tagging and could potentially use the possibilities offered by the semantic web. Cloud computing will provide a distributed and efficient way to store and access this information.
- Organization of learning content and collaboration - Content and teachers will be available on-demand from anywhere in the world through the network. Various new search engines will provide relevancy and accuracy for finding suitable learning content.

7. Conclusion

It is proposed a framework of cloud based learning system for risk analysis of the Bulgarian electricity transmission and distribution network under natural hazards. The learning system includes several components: lists with monitored objects and predominant natural hazards on Bulgarian territory with their characteristics and locations in GIS; potential impacts caused by the natural disasters described; quantitative and qualitative methods for risk analysis and assessment of risk levels. The risk analysis results (the complex risk levels) obtained with the proposed learning system can support the all stakeholders to take more informed decision about effective protection of the electricity network from natural hazards.

The effective protection of the electricity network to can ensure the continuity of the all activities on the Internet as e-Education, e-Business, e-Management, e-Learning.

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References

[1] Organization for Security and Co-operation in Europe – OSCE. (2016). *Protecting Electricity Networks from Natural Hazards*. Vienna, Austria.

[2] Power Outage. (2017). Disaster Survival Resources. Retrieved from the website: http://www.disaster-survival-resources.com

[3] Tzvetkova, S. (2011) Globalization: A factor for Increasing the freight of energy resources. *Proceedings of the Jubilee Scientific Conf. "Transport in Global Economy"* (pp. 37-44). Sofia: UNWE's Publ. Complex.

[4] Wackrow, J. (2017). A guide to business continuity planning in the face of natural disasters, IDG contributor network. Retrieved from the website: https://www.csoonline.com/article/3193616/physical-security/a-guide-to-business-continuity-planning-in-the-face-of-natural-disasters.html

[5] Barkley, P. (2004). Disaster-recovery plans focusing on business continuity, industry report - Enterprise IT. Retrieved from the website: https://www.ecommercetimes.com/story/35993.html

[6] Schmidthaler, M., Reichl, J. & Cohen, J. (2014). Assessing the socio-economic effects of power outages in the European Union ad hoc using www.blackoutsimulator.com. CIRED Workshop, Rome.

[7] Anderson, S. (2016, September). School power outages mean more than canceled classes. Retrieved from the website: http://www.powerprotectionresource.com/articles/425439-school-power-outages-mean-more-than-canceled-classes.htm

[8] Power, R. (2017, September). Is your business ready for a natural disaster? This is how to get ready. Retrieved from the website: https://www.inc.com/rhett-power/is-your-business-ready-for-a-natural-disaster-this.html

[9] Williams, G. (2017, September). Natural disaster recovery: How the online part of your business can help while you rebuild. Retrieved from the website: https://www.americanexpress.com/us/small-business/openforum/articles/natural-disaster-recovery-online-part-business-can-help-rebuild/

[10] ISO. (2009). *IEC/ISO 31010:2009 Risk Management - Risk Assessment Techniques*.

[11] UNISDR. (2009). UN international strategy for disaster reduction sec. Retrieved from the website: www.unisdr.org/eng/library/lib-terminology-eng.htm

[12] Arina, T. (2011). Cloud learning as universal primary education. Retrieved from the website: http://tarina.blogging.fi/2011/11/12/cloud-learning-as-universal-primary-education/

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