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Simulation Tools for Training in the Case of Energy Sector Crisis

H. Malachova, A. Oulehlova, D. Rezac

Abstract**—**Crisis preparedness training is the best possible strategy for identifying weak points, understanding vulnerability, and finding possible strategies for mitigation of blackout consequences. Training represents an effective tool for developing abilities and skills to cope with crisis situations. This article builds on the results of the research carried out in the field of preparation, realization, process, and impacts of training on subjects of energy sector critical infrastructure as a part of crisis preparedness. The research has revealed that the subjects of energy sector critical infrastructure have not realized training and therefore are not prepared for the restoration of the energy supply and black start after blackout regardless of the fact that most subjects state blackout and subsequent black start as key dangers. Training, together with mutual communication and processed crisis documentation, represent a basis for successful solutions for dealing with emergency situations. This text presents the suggested model of SIMEX simulator as a tool which supports managing crisis situations, containing training environment. Training models, possibilities of constructive simulation making use of non-aggregated as well as aggregated entities and tools of communication channels of individual simulator nodes have been introduced by the article.

Keywords**—**Energetic critical infrastructure, preparedness, training, simulation.

I. Introduction

SUBJECTS of energy sector critical infrastructure perform training even if legislation does not require it [1] because they are aware of the importance of crisis preparedness. The single document in the Czech Republic dealing with monitoring training is Act No. 239 on Integrated Rescue System [1]. However, this Act is mandatory only for the components of the Integrated Rescue System, and the subjects of the critical infrastructure do not have such obligation. Most subjects to the performed research [2], state blackout, and subsequent black start as key dangers. According to the law [3], the security liaison employee and the company management are mainly responsible for the preparation and realization of the training. Subjects of energy sector critical infrastructure implement both in-house and coordination single-level and multi-level training which do not use any tools for modeling and simulation. They are mostly represented by theoretic staff training or eventually a “live simulation” is carried out, which is, however, organizationally, logistically and financially considerably demanding [4].

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II. Current Situation Analysis

A. Energy Systems as the Element of the Critical Infrastructure

Energy sector ranges among the most vulnerable components of the critical infrastructure because, without it, the functionality of many other components of critical infrastructure are restricted, the e.g. system of water supply, sewer system, communication and information systems, transport system, emergency services as well as banking and financial sector. Energy infrastructure consists of energy companies ensuring energy transformation – refineries, power plants, heating plants as well as energy transport – oil and gas pipelines, power lines and heat lines [5], [6]. The vast majority of these companies are in the hands of private subjects [7], [8].

The energy system is threatened by various events, either by natural disasters, technology accidents, or failure of the human factor, terrorist attack, and defects in materials, insufficient maintenance, and aging of the material. It can be concluded that the most vulnerable are terrestrial and above ground objects, especially, power lines, gas, and other pipelines, because they represent unprotected long line constructions leading through the areas with free access. The greatest problems can be observed in electricity because it cannot be stored and can cause cascade and domino spread of crisis situations.

B. Blackouts around the World and in the Czech Republic

Examples of long-term blackouts in electricity supply are known from abroad. For example, in 2013, a vast electricity blackout occurred in the north-east part of the USA and in southeast Canada, which affected approximately 50 million inhabitants. A big number of interacting problems which led to the damage to the net occurred, e.g. negligence in the maintenance of vegetation along the backbone power lines, inability to reveal problems in the net and communicate with neighboring energy power lines, insufficient training of the dispatchers and lack backup systems [9]. Italy suffered another blackout the same year, which eliminated the power line supplying Italy from Switzerland and which affected 56 million inhabitants. The cause of this blackout emerged from the whole number of cumulated failures and wrong interventions when the backbone power line between Switzerland and Italy (Mettlen – Lavorgo) was heavily overloaded and short-circuit with the surrounding vegetation occurred. The operators were not able to solve the situation immediately and the overloading of the second key power line between Sils and Soazza took place due to heavy transboundary flows of energy in a short time period. The blackout of the second backbone power line initiated the domino effect and discontinuation of all other lines. The Czech Republic suffered blackout as a result of Kyrill tornado in 2007 and windstorm Ema in 2008 when the blackout was caused by uprooted trees and strong wind which resulted in nearly one million of households disconnected from electricity supply [7].

III. Requirements Engineering of Energy Critical Infrastructure Entity

Research [4] with the use of requirements engineering [10] was carried out among addressed stakeholders from the national energy sector critical infrastructure; relevant ministries, designated bodies of energy sector critical infrastructure and emergency management authorities. The stakeholders were individually interviewed regarding activities, cooperation and collaboration among the crisis management agents and energy sector critical infrastructure in the exercises focused on the analysis of their impact on the environment. The interviews were carried out with the use of questionnaires. Due to the small number of entities, a so-called exhaustive investigation [11] was opted for. The survey results showed that critical energy sector infrastructure entities implemented exercises beyond the scope of the legislation. The exercises had either a particular character of one-level in-house training, or they were realized in cooperation with municipal authorities and the IRS units. No simulation tools were used in preparing or running the exercises. Simulators were used only exceptionally, mostly for risk analysis and analysis of the extreme events impact spreading and as a means for support crisis and emergency planning as well as decision-making. In the case of cooperation training, the time necessary for its preparation extended to half a year or even more. No subjects of energy sector critical infrastructure used the simulator for the support of preparation and realization of the training [4].

IV. Simulation Tools for Training

Simulation and training using simulation technologies are spread in a wide spectrum of fields and activities e.g. in designing constructions when various effects which can influence the construction (earthquake, flood, wind) are simulated. Expansion of simulations is strongly supported by reducing prices of technical devices and the pressure on savings. However, complex simulators for the headquarters training or controlling organizational units are available (with some exceptions) exclusively in military facilities [12], [13].

The conducted research [4] has revealed that the subjects would appreciate if the development of the simulator concentrated on communication area and information transmission during blackout and black start. Results of interviews and questionnaire survey are to be further used for the development of the training scenario and for the development of the simulation device for training cooperation of the subjects of crisis management.

A. Training Models and Simulation Tools

Training models and tools of live, virtual and creative (constructive) simulation can be used for preparation and training of the staff and organs of the crisis management. Experience from abroad shows that training models and simulators can be used to the greatest extent to improve the quality of both individual and group education, preparation and training especially in such areas in which the possibility of direct experiments is highly restricted, which strongly corresponds with the case of energy blackout. The advantage of simulation is represented by the events close to reality during which the trainees can apply their knowledge gained in theoretical lessons in the area of crisis management e.g. in the company IRIT [14], they verify the knowledge and recommended approaches and gain skills or improve their habits and attitudes. No restrictions are applied to the creation and use of training models. Training models and simulators have to be adapted to the objectives of preparation and training as well as to the characteristics and extent of trained situations. Exercises are divided according to preparation and training objectives into the following categories:

1) Drill exercises.
2) Cooperation exercises.
3) Testing exercises.
4) Experimental exercises.

Crisis preparedness exercise can be implemented at the central, departmental, regional, and municipal level as well as at the level of response units. Exercises are organized as a single-level or multi-level, as a staff exercise or exercise with participation of executive authorities. The following basic types of models are especially used for simulation:

1) Verifying models.
2) Training models.
3) Models for the support of decision-making.

Verifying models are used for analyses, searching and verifying the ways and processes in dealing with the current or expected problems, for running scientific experiments and hypotheses testing. Verifying models cannot be created as general or typical, but they have to be always related to the concrete objects i.e. be a model of a unique original and have to display time i.e. they have to be a simulation model. While the training models enable to practice orientation agility, enhance independence, develop creativity in decision-making and gain and straighten the habits of individuals and groups, models for the support of decision-making aim at increasing objectivity and efficiency of the training process. These models started to be used in the military field; therefore, they are addressed to as staff models.

For the purposes of the SIMEX simulator, training models are used because they are able to improve quality, intensity and efficiency of education, preparation and training itself and last but not least improve preparedness and abilities of the staff and organs of crisis management by simulating emergence and development of the crisis situations as well as synergy in influence of their sources and domino effects which often appear in the area of energy sector critical infrastructure. The subject in the process of training is located in the environment closely related to that in which the activities, and is preparing to deal with, take place. Simulators enable to test preparedness, abilities, and reactions of the trainees in the very process of solving the crisis situation, make records of the actions and reactions of the trainees, enable objective analyses and feedback as well as repeating the situation if it is mastered insufficiently. The important aspect is represented by a decrease in the demands on personnel requirements on the number of people integrated into the training because the reactions of the stunts are simulated as well as activities of managing and executive organs which are not involved in the training.

Methods of training with the use of simulations and modeling are used for the preparation of the protection management of critical infrastructure because they are especially suitable for clarification, detection, and training of context. It has proved that by applying applications especially on military and security issues, it is possible to reach the successful dealing of the teams in real situations which have been intensively trained before. Without training, the consequences of incorrect decisions can bring far-reaching effects on the economy, security, lives, and health of people, property and environment.

The tool for the support of managing crisis situations is a newly developed SIMEX simulator which software, communication, and supportive means enable in the real time carry out simulation enabling performing training of the activities of the participants interested and taking part, organizations, organs and systems. The suggested training solution is tested, verified, and interpreted on the virtual scene containing real geographic data and models of participants with the maximal consideration of requirements, processes, and real possibilities and abilities of the final users.

B. Simulated Entities

Simulating applications which make use of constructive simulation can contain non-aggregated or aggregated entities. Non-aggregated entities are represented by e.g. individual vehicles or persons, which is suitable for the training of units where the emphasis is put on the level of detail of the simulation. In the second case of aggregated entities, they are represented by the group of vehicles or people. This helps to simplify both the simulation and the operating of the simulating system which is desirable in large-scale exercises. Simulation system for the solution of cooperative training enables simultaneous use of both non-aggregated and aggregated entities with the aim that the non-aggregated entities are used for the more detail capturing of the areas of interest during the simulation, e.g. emergency work in the direct proximity of the object of critical infrastructure while the aggregated entities are used for simulating actions and activities in the surrounding areas e.g. inhabitants, transport. Further on, special type of "functional" (complex) entities is applied due to the focus of the simulation system, which contain, in a suitable way simplified, process models of specialised facilities e.g. hospitals, substations where the input and output parameters are defined as well as the process of their transformation in time during the use of other means. The simulator also contains some other models complementing environment e.g. models of traffic and transport in a reasonable degree of detail.

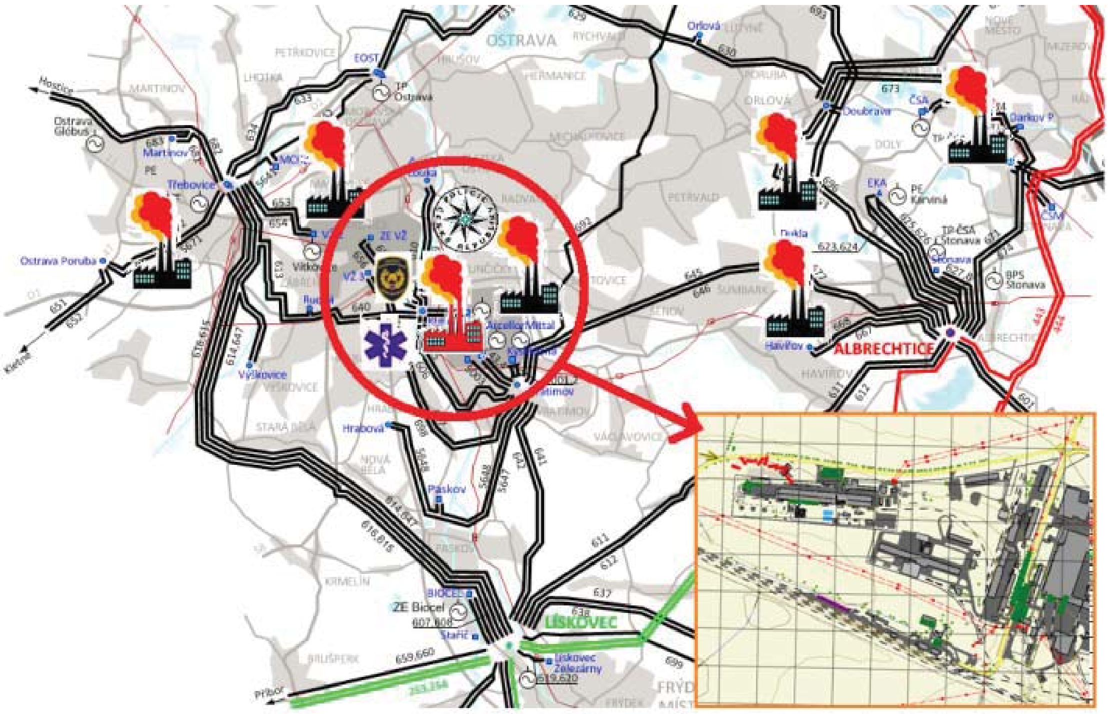

Fig. 1 Display of the Area of Simulation with Marking of the Simulated part without Aggregation

C. Workplace Design for Training with the Use of Simulation Means

Even if every exercise is unique in its preparation and realization part, a systematic approach (Fig. 2) can be established for the organization of the group exercise with the use of simulation means.

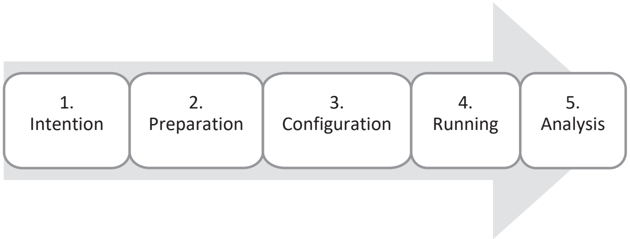

Fig. 2 Display of the Use of Workplace for the Training

1) Exercise has to be ensured both organisationally and technically. From the organizational point of view, it is necessary to determine participants of the exercise, type, and topic of the exercise, aim of the exercise, way of evaluation and its extent and term and place for the exercise performance. This information forms part of the document called Plan of the exercise execution [15].
2) From the technical point of view, it is necessary to prepare the initial situation in the simulation system, i.e. create models of the location and environment, events, forces and means and later prepare the plan of the start, in which the roles and tasks of participants and rally are determined as well as the expected timeline of the activities and events which can appear in reality and which are considered to be real for the purposes of the exercise together with the simulation of the activity of non-exercising organs [15].
3) In another phase, it is necessary to configure the means of the training workplace, especially the system of constructive communication which forms the backbone of the whole training facility. It is essential to distribute the forces and means as well as other entities in a synthetic environment, assign roles to the service (operators), set the supportive means e.g. tools for (semi)automated evaluation of the exercise and configure the nodes of the communication system. The workplace should be equipped with supportive means, which are the means of simulated communication system substituting real communication means of the trainees (phones, transmitters, etc.). It is also essential to prepare materials for all exercise participants i.e. for the trainees as well as technical support – simulator operators, rally, and referees.
4) Before the very start of the exercise, the preparation of trainees and service in the form of briefing is vital. The whole course of exercise i.e. sequences and development of events and reactions in the simulated virtual world and the activities of the trainees, especially in the area of communication are synchronically recorded. The recording can be used not only for the feedback of the exercise but also for creating the statistical output from the course of the simulation. It plays its important role also in controversial situations when performed activity has to be re-played to be able to evaluate it objectively. The recording is also used in subsequent discussions on the alternative approach to dealing with the situation emerged, which enriches participants of the exercise with the alternative ideas [12]. The scheme of the trainees' activity, as well as the people who ensure exercise realisation through the simulation technique, can be seen in Fig. 1, where one can also observe the isolation of trainees and the certain level of the rally from the simulation system. The referee can also provide ongoing notes in the key points of the exercises into the exercise recording. At the same time, continuous evaluation of quality of decision-making according to the pre-set criteria e.g. threat, involvement of citizens, threat or damage to the elements of the critical infrastructure, property and environment are continually observed.
5) Repetition of the problematic points and trying alternative solutions can be done based on the continuous evaluation. If needed, so called operational skips can be performed, i.e. skip the time periods without "action". After finishing the exercise, course analysis takes place as well as overall evaluation based on the recording with the use of supportive means. Results are presented to the participants. Training facility is continually being improved thanks to the feedback. In training solutions of this type, it is necessary to consider that the continuous development (incorporation of new threats, relations, processes etc.) should take place. The reason is to maintain the training solution to remain actual and with practical usage [12]. Evaluation of the exercise contains evaluation of meeting the targets, activity of the trainees, shortages found as well as measurements to be introduced to remove the observed shortcomings including deadlines [16].

D. Simulator Communication

Simulator is designed on the „client-server" architecture basis. A relatively low-level access was used which is very flexible but ensures shielding of the communication level of the operation system from processing data by the simulator. At the same time, communication protocols containing mechanism which ensures safe delivery of the massage (TCP) or its effective distribution among more nodes (PGM) are used.

Object database containing actual status of the simulation is built over this communication level which ensures synchronisation of the objects among the nodes in the simulation. Simulation models themselves work with the objects contained in this database Based on the simulation, modification of the parameters of the objects and subsequent distribution of changes among the clients of the simulation by the means of the operating server takes place. Fig. 4 shows transfer of data among the individual nodes of the simulator.

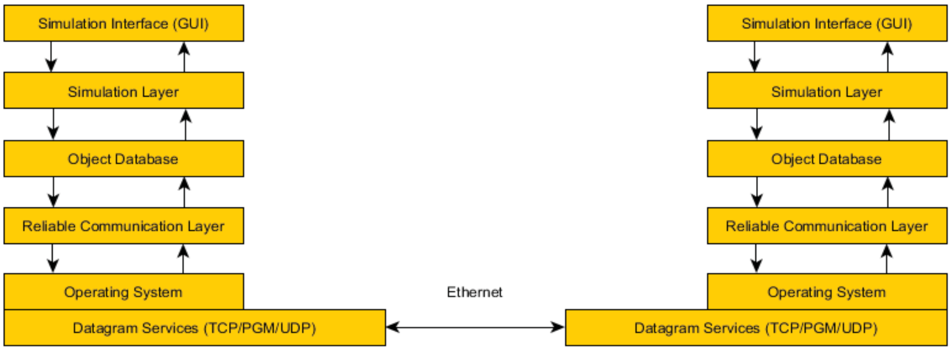

Fig. 3 Data Transfer between the Nodes of the Simulator

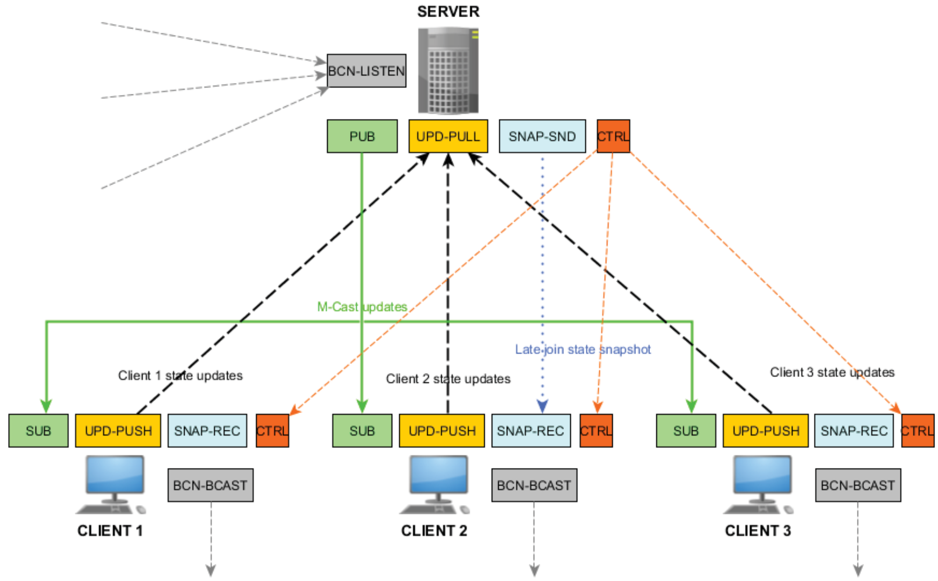

Fig. 4 Communication Channels of the Simulator Nodes

Basic functions concerning communication for the server and its related communication channels listed below in brackets and shown in Fig. 4 are the following: server ensures the presence of the clients in the net (BCN-LISTEN), maintains their list and reacts to the possible loss of communication, founds the simulation (choice and configuration of the area, basic configuration and parameterization of the simulation), dispatches the command to connect or disconnect to the simulation for the clients (CTRL), controls the process of late connection of the client into the exercise, when it is necessary to pass the simulation status to the new client (CTRL, SNAP-SND, UPD-PULL), reads and loads the overall status of the simulation into the storage (file/database), controls the simulation – start-up, pause, restart (PUB), collects updated data (updates) from individual clients (UPD-PULL) and distributes them collectively to all participants in the exercise (PUB), collects commands from clients (UPD-PULL) and process them, or distribute them to other participants in the exercise (PUB). Another basic function for the clients and communication channels listed in the brackets are the following: periodically announces its presence and status in the net (BCN-BCAST), according to the server command, it connects/ disconnects to the exercise (CTRL), based on the credits sent by the client (UPD-PUSH), it obtains data from the server in case of late connection (SNAP-REC, CTRL), reacts to the server commands (SUB), sends updated data (updates) to the server (UPD-PUSH), receives updates of other clients mediated by the server (SUB).

V. Conclusion

Practical exercises on the model, but on the other hand real, situations are for the education of people in the area of critical infrastructure highly efficient and beneficial, especially in the energy sector critical infrastructure. Training represents an effective tool for mastering abilities and skills to cope with crisis situations. Subjects of energy sector critical infrastructure perform training even if legislation does not require it, because they are aware of the importance of crisis preparedness. Participants taking part in the exercise, who play their role in it, can better understand the extent and impacts of their decisions, check their communication skills, test their ability of interpretation as well as evaluation of information, because the communication among individual intervening components represents one of the most challenging items. Problems in communication were also revealed by the results of the training activities for blackout carried out in Prague and Brno. In case of danger emergence in more regions, importance of crisis communication increases.

Training with the use of simulation means represents a tool enabling interconnection of both theoretical scientific knowledge and managing abilities. Training, together with mutual communication and processed crisis documentation, represent a basis for successful solutions to dealing with emergency situations. No subjects of energy sector critical infrastructure have not used simulator for the support of preparation and realisation of the training before. Subjects would appreciate if the development of the simulator concentrates on the communication area and information transmission during blackout and black start. This article describes suggested environment for the training with the use of simulation means together with proposed aggregated as well as non-aggregated entities, elements of the training environment and architecture design based on the client-server principle with basic functions concerning communication.

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