TECHNIQUES FOR THE ANALYSIS OF INCIDENTS IN THE ELECTRO-ENERGY FACILITIES

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Abstract - The paper proposes techniques of probabilistic approach for automated assessment of possible incidents and response using Bayesian networks logic. It is analyzed a risk assessment based on Bayesian networks taking under consideration a wider range of observations linked to the equipments risks, and human behaviour, and on their basis computing the probability of happening an incident and its gravity. The observations of the potentially unsafe human behaviour can be set using sensing/detection devices. The qualitative risk assessment made in real time thorough Bayesian inference updates in real time the probability estimate for the hypothesis of an unsafe situation as additional evidence is learned throughout the data sets collected. If the possibility of an incident to happen is high, determined before it'll happen then will be provided enough time for automated or human assisted response.

Keywords: incident, risk assessment, human behaviour, Bayesian networks.

1. INTRODUCTION

Safe working of individuals on electro-energy facilities is provided by today's safeguards and recommended work practices.

There are three ways to perform electrical work: offline working, live working, and working in the vicinity of live parts. All these have different working methods, safety procedures that must be followed, and/or safeguards. Most electrical works are supposed to be done offline, but almost all occupational electrical accidents occur during offline working or work that was supposed to have been performed offline.

The safeguards are mainly implying earthing, grounding of the equipments, or using ground fault circuit interrupters. The workers should wear the personal protective equipment (PPE) according to the risks that they are exposed to [7].

Also, the workers should follow procedures that they are trained with, verified and authorised to[7].

One of the important procedures used in the electrical industry for providing safety of the workers in is the Lock Out / Tag Out (LOTO) procedure. According to it the electrical power must be removed when electrical equipment is inspected, serviced, or repaired. To ensure the safety of personnel working with the equipment, power is removed and the equipment must be locked out and tagged out. The equipment should be locked out and tagged out before any preventive maintenance or servicing is performed. Lockout is the process of removing the source of electrical power and installing a lock which prevents the power from being turned ON. Tag out is the process of placing a danger tag on the source of electrical power which indicates that the equipment may not be operated until the danger tag is removed.

Lockouts and tag outs do not by themselves remove power from a circuit. They are attached only after the equipment is turned OFF and tested to ensure that power is OFF. The lockout/tag out procedure is required for the safety of workers due to modern equipment hazards. Lockouts are performed using lockout devices that are lightweight enclosures that allow the lockout of standard control devices, such as plugs, disconnects, etc.

The main importance of a lockout device is that it is individually keyed. Practically the key is on the person that performs the work on the locked system.

The main causes of accidents, ending with casualties, in the electric power industry are due to failures to de-energize, test, earth, or secure against accidental energize. These are determined mainly by the failure of following the safety procedures due to the unsafe behaviours of the workers performing the job.

At the level of the organization, its workers safety is provided by implementing and maintaining a good health and safety management system. Such health and safety management systems are based on elaborating policies, procedures, training of personnel, establishment of comities and councils for health and safety, and compliance with the legal regulations or standard requirements. Looking at the causes of accidents that are mainly consisting of human errors and violations it doesn't mean that if the workers are trained with these procedures, or know them, will also follow them.

Electrical safety training that merely covers the work practices spelled out in the legal requirements is lacking in that simply knowing the rules doesn't equal following the rules. Practically is needed a training that not only outlines the safe work practices but also why they must be followed.

It is needed to change at-risk behaviours by urging workers to adopt new electrical safe work practices. In order that the health and safety management system is implemented to make a difference, training time must be spent on the health and safety culture of the workers in order to alter their risky behaviour [8].

2. BEHAVIORAL BASED SAFETY APPROACH

More than half a century ago, Heinrich (1959) stated that the identification of accidents' underlying causes ("sub causes") is an important part of accident prevention [3]. He divided the immediate causes of preventable accidents (98% of all accidents) into unsafe acts (88%) and mechanical or physical hazards (10%). As mechanical and physical hazards are also due to some kind of human input, he argued that all underlying causes behind immediate causes are related to "faults of persons"[3]. According to Heinrich, the underlying causes of unsafe acts can be grouped as the headings of improper attitude, lack of knowledge or skill, physical unsuitability and improper mechanical or physical environment. Besides industrial hygiene and ergonomics -related elements, Heinrich included under the environment-heading those elements, which today are grouped under organizational factors, e.g. company policy, procedures and safety rules. The human behaviour is anything that is an observable action about an individual.

Because behaviour is both observable and measurable, so therefore the behaviour can be managed.

Behavioural Based Safety is an excellent tool for collecting data on the quality of a company's safety management system. It represents a scientific way to understand why people behave the way they do when it comes to their or their fellow workers safety.

The BBS approach is founded on behavioural science as conceptualized by B. F. Skinner [5]. Experimental behaviour analysis, and later applied behaviour analysis, emerged from Skinner's research and teaching and laid the foundation for numerous therapies and interventions to improve quality of life.

Properly applied, Behavioural Based Safety is an effective next step towards creating a truly pro-active safety culture where loss prevention is a core value.

Most experts believe that human behaviour is primarily controlled by the "ABC model" of Activator—Behaviour—Consequence [4].

Activators refer to the fact that people behave the way they do because they are activated to do so. Activators can be someone's voice, a phone ringing, a "Do and Don'ts List", safety sign or pictogram, training, procedure, etc. Activators can be either conscious or subconscious.

Behaviour is a reflection of our knowledge, training and competence and can be intentional or unintentional.

Individuals are most often motivated to repeat behaviour, by the consequences or enforcements experienced from previous behaviours. Consequences are the most powerful force, therefore the consequences of a person's actions determine whether he or she will continue or increase the desired behaviour or discontinue or decrease it.

Behaviours are also affected by people's attitudes about risk. This knowledge helps us to minimize unsafe behaviour by making workers aware of why they behave the way they do, what is a safe and unsafe behaviour, and what can be done to minimize unsafe and encourage safe behaviours.

Consequences influence behaviour based upon three factors: timing, consistency, and significance. Significance is dependent on magnitude and impact. The different combinations of these factors will determine the likelihood of behaviour increasing or decreasing in the future.

Timing refers to the cases if the consequence is immediate or if it may happen in the future.

Consistency refers whether the consequence is certain to happen or is there uncertainty.

Significance refers to whether the consequence is viewed as positive or negative by the person who receives the consequence. Significance means is the consequence of large or small magnitude and what impact does it have on the person receiving it.

The critical point in Behavioural Based Safety is that activators or signals preceding behaviour are only as powerful as the consequences supporting them. That is, activators tell people what to do to receive a consequence, from the ringing of an alarm, telephone to the instructions from a health and safety training seminar or one-on-one coaching session. People follow through with the particular behaviour activated to the extent they expect doing so will provide them a pleasant consequence or enable them to avoid an unpleasant consequence.

The BBS approach applies this ABC principle to design interventions for improving behaviour at individual, group, and organizational levels. More than 40 years of research in the behavioural sciences has demonstrated the efficacy of this general approach to directing and motivating behaviour change.

The principle of focusing on positive consequences to motivate behaviour provides more specific direction for designing an intervention.

The use of punishment (or negative consequences) to motivate behaviour is not always the solution because, according to Skinner "The problem is to free men, not from control, but from certain kinds of control" [6].

Therefore control by negative consequences must be reduced to increase perceptions of personal freedom.

Unfortunately, the common metric used to evaluate and rank companies on their safety performance is the total recordable injury rate (or an analogous count of losses) that puts people in a reactive mindset of avoiding failure rather than achieving success. I the BBS approach there are provided proactive measures that employees set goals to achieve to reduce occupational risks and prevent unintentional accidents.

Behaviours can be objectively observed and measured before and after an intervention process is initiated. This application of the scientific method provides feedback for cultivating improvement.

The results from such testing provide motivating consequences to support this learning process and keep the workers involved.

Often there are three types of behaviours corresponding three kinds of intervention approaches:

- Instructional intervention - an instructional intervention and typically it is used an activator or antecedent event to get new behaviour started or to move behaviour from the automatic (habit) stage to the self-directed stage. This type of intervention consists primarily of activators, as exemplified by education sessions, training exercises, and directive feedback.

• Supportive intervention when a person learns the right way to do something, practice is important so the behaviour can become part of a natural routine. Continued practice leads to fluency and in many cases to automatic or habitual behaviour. Although instructional intervention consists primarily of activators, supportive intervention focuses on the application of positive consequences.

• Motivational intervention is needed when people know what to do but don't do it, so they require some external encouragement or pressure to change. Instruction alone is obviously insufficient because they are knowingly doing the wrong thing. In safety, this is referred to as a calculated risk. People take calculated risks when they perceive the positive consequences of the at-risk behaviour to be more powerful than the negative consequences. The positive consequences of comfort, convenience, and efficiency are immediate and certain, whereas the negative consequence of at-risk behaviour (such as an injury due to an accident) is or seems improbable. In this situation an incentive or reward program is useful. It attempts to motivate a certain target behaviour by promising workers a positive consequence if they perform it. The behavioural impact of these enforcement programs are enhanced by increasing the severity of the penalty and punishing more people for taking the calculated risk.

3. APPLYING BAYESIAN NETWORKS TO ASSESS OCCUPATIONAL RISKS

There are a number of assessment methods, such as fault tree analysis, which used in tandem with an efficient probabilistic method may lead to optimal results.

Probabilistic graphical models are graphs in which nodes represent random variables and arcs (or lack thereof) are the conditional independence assumptions. As a result, they provide a compact representation of the cumulative probability distribution. Undirected graph models, also called Markov Random Fields and Markov networks, have a simple definition of independence: two (sets of) nodes A and B are conditionally independent if, given a third (set) C, all paths between nodes A and B are separated by a node in C. By contrast, directed graphical models - also called Bayesian networks have a more complex notion of independence, which takes into account the direction of arcs, with several advantages, the most important being that an arc from A to B can be interpreted as a "cause" on B. This can be used as a "guide" for the construction graph. In addition, oriented models can encode deterministic relationships and are easier to learn, or to implement [2].

Causal structure and conditional relationships that are registered in the model, allow entering information via input nodes, their propagation through model and the modification of the output nodes.

Given all the above, you can build a conceptual model for safety analysis system based on Bayesian networks (Fig.1).

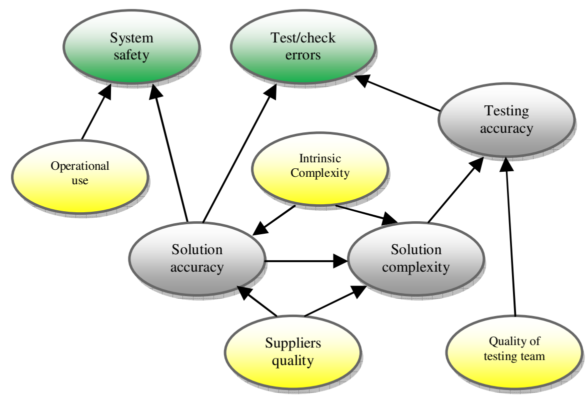

Fig.1. Model analysis of the safety of a system based on Bayesian networks.

This model can be used for both predictive and diagnostic interpretation, thus providing decision support.

The system safety can be achieved thorough the proper operational use and the accuracy of the solution, whereas the latter depends on quality of the suppliers and the intrinsic complexity of the problem. In the same manner it is analysed the testing errors.

To achieve logic safety monitoring system it can be developed a model based on Bayesian networks as shown in Fig.2.

By implementing this model, it can be achieved a state of risk assessment based on several observations were extended at cost. Several causes triggers (human, machine or environmental) and state of the system at a time can lead to system to entry in a dangerous situation. The dangerous situation may arise because by design a risk could not be eliminated and therefore resulting a residual risk. Residual risk event is determined by the dangerous condition of the system and can be mitigated or eliminated with existing security barriers, with implications for human factor and revenues. Depending on the perception of risk it may be initiated an action that avoids an accident and directly affects costs.

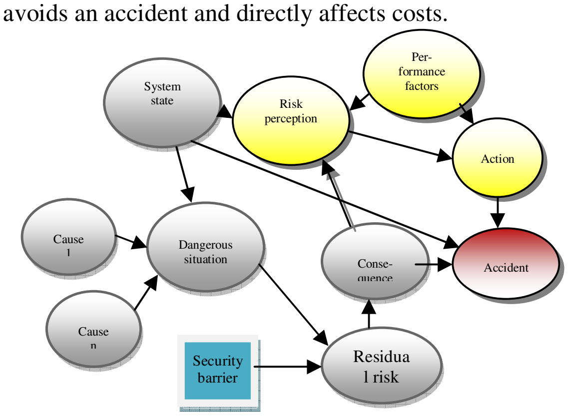

Fig.2. Risk monitoring model based on Bayesian networks.

A method for risk assessment using Bayesian networks is to build Bayesian model taking into account the observations related risk factors determined by work equipment, work environment, work task and worker behaviour, based on calculating the probability of occurrence of an accident and its severity [1].

Since risk is the combination of the probability of occurrence of a hazardous event and the severity of its consequences, it may be used scheme for evaluating the risk with four levels of probability and 4 levels of severity (Figure 3).

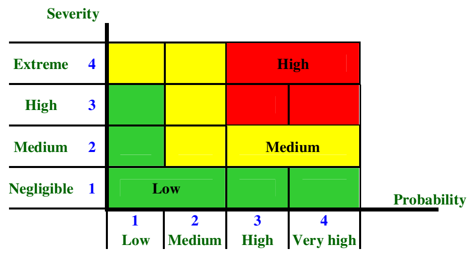

Fig.3. Risk assessment grid

The method consists of several steps:

• The first step that is performed is to identify causal factors generated by work equipment, work environment, job task and worker behaviour.

• The next step is to construct the influence diagram, which establishes causal relationships between causal factors.

• The third step, consists in building the Bayesian network, determining intermediate factors and causal relations in which they may be involved, and determining the distribution tables. Distribution tables can be completed with grades of certainty based on statistical data on those cause factors, or data resulting from management reviews, depending on the experience of the designer.

• The last phase of the method consists of the assessing of the level of risk by applying Bayesian inference.

Unlike tree analysis of failure, Bayesian networks can use a variety of types of information incorporated in the same model, thereby expanding the range of use of the product that uses it. However, relations between the variables of Bayesian networks are moreover probabilistic rather than deterministic. Deterministic relations are basic feature in the Failure Tree Analysis and other risk management tools. Probabilistic relationships between data elements, allow uncertainty to be encoded in the model, this is very important since it helps to represent an uncertain world, being analogous to the way the human factor perceives the world.

Thus, the analysis and representation of a system using a model based on Bayesian networks, is allowing real-time probabilistic assessment of potential dangerous situations and depending on the security policy, also the establishment of effective decisions.

Using a logic based on Bayesian networks it can be implemented a real-time assessing system that takes under consideration also the at-risk behaviours, setting the observations from the real world into the causal nodes of the model.

Because the risk behaviour is observable, for real time behaviour computerized monitoring may be used with sensors and cameras that imply image recognition algorithms, and different other data like statistics, etc.

By applying inference it may be calculated in real-time the probability of arising of a dangerous situation and accident. If the probability of an accident is high, then the system can take a preventive action and log the risk factors, if the probability is low, then it may log the risky situation and risky behaviour so the appropriate measures should be taken in the future. Like this the risky behaviours of workers could be learned and the data collected could serve to improve the organisational preventive actions like behavioural analysis, customized training and behavioural changing techniques.

5. CONCLUSIONS

There are numerous methods available for analyzing data representation such as sets of rules, decision trees and neural networks, there are also many data analysis techniques as: density estimation, classification, regression and clustering.

The Bayesian networks allow the study of causal relationships, and this process is useful when it is desired to understand a range of problems. Moreover, knowledge of causal relationships allows us to make predictions for interventions.

Bayesian networks in conjunction with Bayesian statistical techniques and behavioural analysis facilitate knowledge combined with field data. We know that all the knowledge previously gained is of great importance in the study of real-world problems, especially when data can help analyze their collection is not complete or induce high costs. The fact that some commercial applications (eg expert systems) can be based on previously acquired knowledge is an asset for this model. Furthermore this approach reinforces the power of causal relations with theory of probability. So, prior knowledge can be combined with relevant data using Bayesian statistical techniques.

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