A METHOD FOR ANALYSIS OF NUCLEAR POWER PLANT OPERATORS' DECISION MAKING IN SIMULATED DISTURBANCE SITUATIONS

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Abstract

An analysis method has been developed for analysis of nuclear power plant operators' decision making in simulated disturbance situations. The aim of the analysis is to investigate operators' orientation which is expected to manifest itself as collective strategies in utilization of resources of decision making. Resources analysed here are different information sources and, in addition, collaborative resources like communication and participation. The cognitive approach on the basis of the method considers decision making as collective construction of common interpretation of available information. Utilization of information is evaluated with respect to operative context. This is made with help of conceptualization of the disturbance situation from the decision making point of view and by construction of operative reference for activity. The latter means conceptualization of the situation from the safety point of view and also consideration of other boundary constraints of decision making, i.e. economical and technical aspects.

The analysis method is intended to be used in routine simulator training in nuclear power plants. By virtue of it's contextual and dynamical approach it makes the developing nature of activity visible. Cumulation and distribution of knowledge of decision making as developing activity, controlled by orientation and boundary constraints of process control, is expected to improve operational culture of a plant organization.

1 INTRODUCTION

Decision making in highly automated work like process control in a nuclear power plant requires intellective skills because the production process is represented in informated form, i.e. as converted into information (cf. Zuboff 1988). The function of these skills is to give meaning to the mediated information automation produces.

Our research group, composed of man-machine psychologists, has a contextual and dynamic approach to analysis of these skills in process control (Norros, in press). This approach has been developed in our research program concerning decision making in informated work, especially on safety critical areas.

According to our view, activity is dependent on it's context and therefore activities are dynamically constructed in concrete performance situations. Consequently, process control operators' decision making should be analysed by taking it's operative and social context as reference of analysis. It is important to clarify how operators take these contexts into account in their collective decision making. We have used the concept of orientation to describe this subjective relationship to the object of activity.

Our approach is also historical in the sense that developmental aspects of activity have been taken into account. Decision making is viewed as developing according to personal development of operators and changes in operational culture.

On the basis of these concepts we have developed a method for analysis of nuclear power plant operators' decision making in simulated disturbance situations. The method has been developed in collaboration with nuclear

power plant operators, trainers and other nuclear power plant experts. Chapter 2 introduces the current phase of our theoretical approach. The method itself will be presented in chapter 3. In the last chapter some aspects concerning it's development and it's usefulness with respect to simulator training will be discussed.

2 CONCEPTUAL MODELLING OF DECISION MAKING IN PROCESS CONTROL

2.1 The model

Our research program was based on need of conceptual tools for analysis and evaluation of process control operators' decision making in a nuclear power plant. A model was developed for decision making in a disturbance situation. It was used as a conceptual tool and developed further in a study concerning nuclear power plant operatos' diagnostic decision making in a simulated disturbance situation (Hukki & Norros 1993). Evaluation of decision making with help of the model was made in collaboration with a nuclear power plant expert.

The model is a conceptual description of operators' collective diagnostic and operative decision making in a particular disturbance situation. In the next paragraphs the basic concepts of the model will be described.

According to our view, diagnosis in the traditional sense means recognition and localization of a disturbance. In this sense it has often been comprehended as fault finding. Diagnosis can, however, be considered in a wider sense, as interpretation of a whole situation. That means recognition of a disturbance with respect to the plant process, i.e. recognition of the degree of disturbedness of the whole process. This wider diagnosis requires

coherent conceptual representation of process dynamics.

The coherence of representation of process dynamics is supposed to depend on a subject's orientation. This concept which we consider as central in evaluation of operators' expertise can be defined, in general, as subjective relationship to the object of activity. Our view is that in a disturbance situation it is a process of framing the situation and therefore it controls the dynamic construction of decision making. Individual orientations of the members of the crew control the dynamics of the construction.This dynamics, i.e. cooperation, can be considered as manifesting something like collective orientation. It's dynamics is dependent on crews' utilization of cooperative abilities of it's members, i.e. of communication and participation.

In evaluation of operators' comprehension of process dynamics a more extensive operative reference is needed than description of ideal task performance. For evaluation of adequacy and dynamics of disturbance handling the disturbance situation must be conceptualized in order to define relevant criteria for evaluation. Safety is the ultimate criteria for decision making in process control in nuclear power plants. Therefore criteria of decision making have to be defined primarily with respect to safety aspects. A feasible reference for evaluation can be created by utilizing the concept of critical safety functions (see e.g. Corcoran et al. 1981). These global functions of the plant process, e.g. mass inventory of the coolant and heat transfer from the reactor core are essential from the safety point of view. Recognition of those functions which have been threatened during the disturbance situation and maintenance of them with help of adequate operative methods can be used as operative reference.

Diagnostic and operative interpretations are constructed on the basis of available process information (on-line information indicating the physical

state of the process) and procedures. On the basis of the arguments mentioned above we supposed that coherence of operators' comprehension can be inferred on the basis of type of their utilization of process information and procedures. The aim of the above mentioned study (Hukki & Norros 1993) was to find out possible differences in utilization of process information in diagnostic decision making. On grounds of the results the model seemed to work. Utilization of process information differed between the crews. There was two types of utilization. Part of the crews made diagnostic inferences directly on the basis of process dynamically informative information, i.e. information which can be used as evidence of the functional state of the whole process or of a functionally essential part of it. Part of them proceeded by using information locationally, by excluding alternative locations of a disturbance. In conclusion, there seemed to be two types of orientation controlling the crews' decision making.

Moreover, orientation seemed to be related to adequacy of diagnostic and operative task performance. Those crews which proceeded by excluding diagnostic alternatives underestimated size of the disturbance which lead to unoptimal operations.

Cooperative aspects of utilization could not be analysed in the study due to deficiencies of the data.

2.2 The extended model

After the before mentioned study our conceptual model for analysis has been constantly developing. The concepts concerning contextual and dynamical aspects of decision making have been elaborated further. Moreover, the historical aspect of decision making has been considered.

The concepts of operative and social context have developed. As to the operative context, it has been widened. According to our current view, in addition to understanding of process dynamics also comprehension of action of technical systems and components with respect to process is essential in disturbance handling. Therefore it is not sufficient to analyse utilization of only on-line process information and procedures. Information sources are also considered more comprehensively, by taking into account also information in the form of administrative directions and technical plant documents. This information concerns aspects like safety restrictions, technical and economical constraints etc. that the operators should take into account in their diagnostic and operative decision making. These aspects affect usability of different operative methods in process control. Considering of this other type of information makes necessary to define respectively it's informativeness with respect.

Consideration of social context of operators' decision making has been widened from a crew to other individuals and groups in the work organization. Decision making will be comprehended, on a more global level, as network of interactions between control room, maintenance, management etc. Requirements and decisions on other organizational levels create constraints for the crew's control room activities.

Evaluation of orientation has been under elaboration, too. On the basis of the results of the before mentioned study it was supposed that there are two different aspects of orientation controlling construction of decision making. They are tendencies to coherence and reflectivity. By coherence we mean coherence of comprehension of the object of decision making activity which in the case of process control is the plant process. Reflectivity is defined as taking into account the context of activity. In the current phase of our approach evaluations of these (and possibly other) aspects of orientation are made in two independent ways, by evaluating operators' activity in decision

making and by evaluating, through interviews, their comprehensions of their activity.

These tendencies are supposed to manifest themselves in operators' action strategies in their decision making. Analysis of these strategies can be made with respect to different types of utilization of resources of decision making. These resources are information sources and collaborative resources.

In the case of the information sources evaluation is based on operators' action strategies in setting their operative goals. The aim is to consider two dimensions of these strategies, constructiveness and situativity. Utilization of information is constructive if activity is directed towards making coherent conception of the state of the plant process on the basis of process dynamically informative high level indicators, i.e. with respect to mass and energy balance. Utilization of information is situative if e.g. diagnostic counter evidence and if usability aspects (e.g. technical or economical constraints) are taken into account in their choice of alternative operative methods.

In the case of collaborative resources tendency to coherence is evaluated as tendency to a common interpretation in construction of decision making and reflectivity as tendency to utilize situatively communicative and participational abilities of one's own and of the other members of the crew.

Taking the historical aspect into analysis of decision making combines the contextual and dynamic aspects of our approach. Decision making is viewed as dynamic construction also on more global level, with respect to orientational changes of operators', training department and other levels of the work organization.

On the basis of this elaborated version of our conceptual model we have

developed an analysis method. The method which will be introduced in the next chapter has been developing during it's preliminary use. Some aspects with respect to this development will be discussed in chapter 4.

3 AN ANALYSIS METHOD FOR DECISION MAKING

The analysis method makes possible to test our theoretical concepts in concrete disturbance situations during simulator training. The aim of the analysis is to have support to our concept of orientation as controller of construction of activity in decision making.

The method offers a tool for systematical conceptualization of crews' task performance as collective construction of diagnostic and operative interpretations on the basis of available information in this specific situation. The crews' task is to stabilize the disturbed plant process during the simulator run.

The method consists of two main parts. The first is creation of operative reference for analysis of decision making and the second is analysis of decision making with respect to this reference.

3.1 Creation of operative reference

In this preparatory phase the operative context of operators' decision making will be conceptualized. An essential feature of the method is that operative reference will be constructed for a specific disturbance situation. Therefore, when applied to a new disturbance situation a new reference must be made.

Creation of reference includes two phases. The first is design and conceptu-

alization of the disturbance situation on a general level and the second is creation of operative criteria for decision making. It is necessary to carry out these phases in collaboration with trainers and other nuclear power plant experts.

3.1.1 Design and conceptualization of the disturbance situation

In the design of the disturbance situation some aspects in addition to normal educational demands should be taken into account. In order to make the degree of operators' professional competence visible disturbedness of the plant process should be serious enough and adequate decision making should require operative choices.

An example of conceptualization of a disturbance situation from the decision making point of view is depicted as a flow model in figure 1. The course of decision making is roughly as follows. In the beginning of the simulator run the trainer gives the crew the necessary information concerning the baseline state of the plant. The disturbance situation begins when the first plant alarms indicate of some kind of a disturbance. The crew makes a diagnosis on the basis of available information. This information includes, on one hand, on-line process information an, on the other, documents like procedures, administrative directions and technical restrictions. On the basis of their diagnosis operators set operative goals in order to stabilize the plant process. These goals can be reached by alternative operative methods. If no method has been chosen the automatic plant protection systems will be activated during a predefined time. The amount of operative goals and therefore of operative choices depends on the situation. A new goal is again based on utilization of current available information.

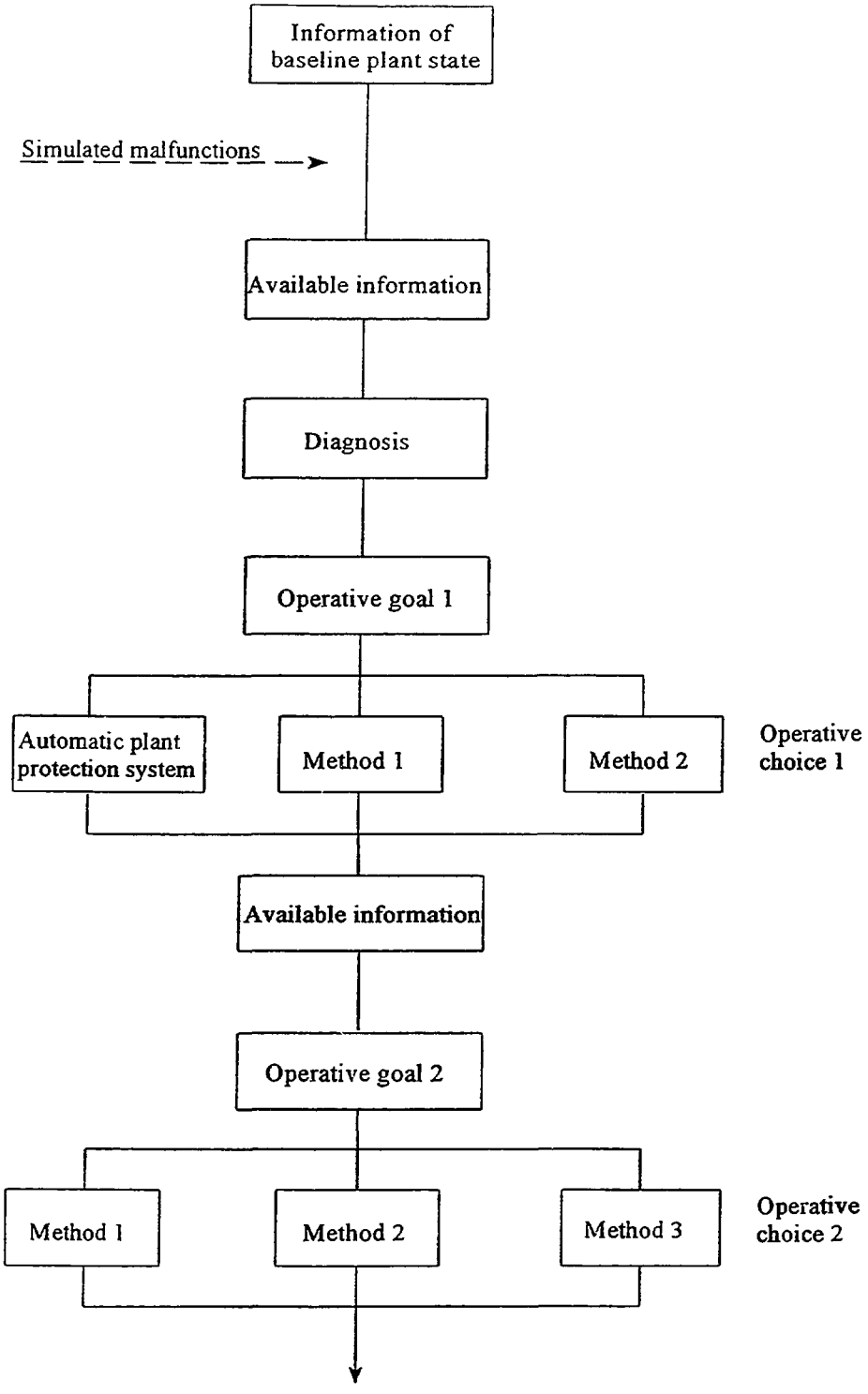

Figure 1 Decision making in a disturbance situation

It is important to note that this kind of conceptualization of a disturbance situation is an oversimplification because in reality a diagnosis can change and there can be parallel diagnoses and operative goals.

The general flow model will be used as a conceptual tool for evaluation of crews' task performance.

3.1.2 Creation of reference tables

Two reference tables are created and used as operative criteria of decision making.

The first one is conceptualization of the disturbance situation from the safety point of view. The situation is conceptualized with respect to the physical state of the plant process according to the concept of critical safety functions. The table is a description of those critical safety functions which will be threatened during the situation and of adequate maintenance of them. It includes those critical symptoms on the basis of which the threatened critical safety functions can be recognized. These symptoms are high level indicators of the functional state of the process. They can be process parameters or indicators of (in)activation of technical systems. Stabilization of the process means maintenance of the threatened critical functions. Maintenance of a critical function can be considered as a high level goal. In the table the adequate operative methods for reaching each goal are presented. These goals and methods are respective to the ones in the flow model in figure 1.

Because the disturbance situation can be handled in different operative way the second table is designed for comparison of alternative operative methods from the usability point of view. This table includes all alternative

operative methods. The comparison will be made with respect to different aspects of usability. From the safety point of view the methods can differ by e.g. their capacity with respect to the critical functions to be maintained and possible risks. Other aspects affect the mutual priority of the alternatives, too. These can be general constraints like economical aspects and technical constraints (complexity of use, dependences on other systems or components etc.). They can also be constraints set by the specific situation, e.g. availability of technical components and systems.

The two reference tables are used as conceptual tools in evaluation of crews' task performance.

3.2 Analysis of crews' decision making

In this phase operators' strategies in decision making are evaluated in order to find out their orientational tendencies. Inferences are made on the basis of their comprehensions of decision making in process control and their strategies in utilization of informational and collaborative resources of decision making.

The method offers different mutually supportive means for clarification of the role of orientation in operators' decision making. One way is evaluation with help of interviews, on the basis of operators' verbalized comprehensions concerning process control. Another is evaluation on the basis of differences in their utilization of resources of decision making. This type of evaluation is made during the simulator run and after it, during a debriefing session. It is necessary to make it in collaboration with a trainer.

3.2.1 Operators' comprehensions of activity

The developed interview is diagnostic with respect to supposed manifestations of types of orientation. It is composed of questions concerning operators' comprehensions of the object of their work (the plant process), of process control activity in general and of their own ways of action. These themes include questions of the plant process as a technical system and as an object of decision making, of available resources of decision making, of professional requirements etc.

Evaluations of operators' comprehensions are made by categorization of them with respect to coherence and reflectivity tendencies and to operative reference tables and by comparing these evaluations with each other.

The operators are interviewed one at a time. The interviews are made before observation of the task performance because they enable getting acquainted with the operators and facilitate the observation. During oberva-tion they make possible to understand better the operators' ways of action and to make comparisons between the verbalized comprehensions and the real process control activities in a (simulated) disturbance situation.

3.2.2 Operators' action strategies during decision making

The object of observation is operators' decision making as construction of interpretation of the disturbance situation and at the same time, as collecti-ve construction of common interpretation. Use of different information sources and collaborative resources are in construction of diagnostic hypotheses and operative goals and in choice of operative methods are observed.

Besides during the simulator run observation can be made also afterwards, on the basis of registrations of the operators' activities and of the physical state of the plant process. These include on-line registrations of operators' verbalizations and movements (in form of video tapes) and operative activities, plant alarms and other indicators of the process state (in form of computer registrations).

Evaluation of decision making is made preliminarily during the simulator run and it is possible to deepen it during a de-briefing session which is carried out collectively with operators. The session is arranged as immediately after the simulator run as possible in order to make sure that they remember details of their decision making. Operators explain their motives and arguments for their diagnostic and operative inferences. The general flow model and the two reference tables are used as conceptual tools. The operators consider their decision making as a route composed of diagnostic phases and setting of operative goals. Their choices of operative methods are considered as alternatives among other possibilities. Handling of these alternatives with respect to safety and other boundary constraints of process control possibly deepen evaluation of their orientation.

Evaluation of utilization of resources of decision making is made with respect to evaluation of adequacy of their process control activities.

Adequacy of disturbance handling, i.e. adequacy of operators' diagnostic and operative inferences is made on the basis of the operative reference tables. Operative goals and diagnostic interpretations as the basis of these goals are considered with respect to reference table 1 from the mass and energy balance point of view.

The crew's choices of operative methods are evaluated with respect to reference table 2 from the view point of consideration of usability aspects.

Chosen methods are marked on the general flow model as a route of decisions.

Utilization of information resources is evaluated with respect to the same operative reference tables. Constructiveness of operators' strategy is inferred by utilization of process dynamically informative informativeness for making coherent conception of the state of the plant process. Situativity of strategy is inferred by consideration of diagnostic counter evidence and usability aspects of alternative operative methods. Inferences from aspects of operators' orientation in decision making are made on grounds of these evaluations.

In evaluation of utilization of collaborative resources operators' tendency to coherence is inferred by considering how individual members of the crew contribute to construction of a common interpretation of the situation. Their tendency to reflectivity is evaluated by analysing how situatively they utilize their own and others' communicational and participational possibilities in use of common information resources.

By comparing different ways of analysis it is possible to clarify the role of orientation as controller of construction of activity in decision making. Investigation of operators' strategies in utilization of information increases knowledge of qualitative differences in operators' disturbance handling. It also enables consideration of possible relationships between these differences and deficiencies in disturbance handling.

4 DISCUSSION

The analysis method described in this paper offers a conceptual tool for systematical evaluation of nuclear power plant operators' decision making

in simulated disturbance situations.

The expected strength of the method lies in it's contextual and developmental nature. It makes possible to design a disturbance situation according to educational needs and to evaluate decision making with respect to it's operative context. In addition to this, it enables consideration of decision making as collective contruction of interpretations controlled by orientation.

The method is aimed to be used in simulator training in nuclear power plants. Collective creation of the operative reference tables during a debriefing session is expected to enhance feedback to the trainees. Due to conceptualization of the disturbance situation with help of operative reference they become more conscious of their strategies in decision making and in cooperation.

Feedback to trainers is expected to increase, too. They become more conscious of their criteria and strategies in their training activity and this will be reflected later in the quality of training.

Along to the development of simulator training, due to the accumulation and distribution of knowledge of decision making considered with respect to it's boundary constraints, the operational culture is supposed to develop.

Accumulation of knowledge of qualitative differences in operators' decision making and also comprehension of importance of orientation in decision making will become more clear. Orientation expectedly influences learning. Tendency to coherence and reflectivity towards own and others' activity enhances professional competence. Learning can be improved also by deliberately developing operators' orientation during simulator training.

Next some aspects concerning the development of our analysis method

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during it's preliminary use. It, too, seems to reflect our concept of contextual and developing nature of activity. The conceptual integration of the method increased all the time through mutual interaction between it's submethods and phases.

E.g. the interview became more concentrated and the importance of the de-briefing increased. Creation of the operative reference became more elaborated and the structure of the de-briefing session better organized by mutual interaction between the developers of the method (researchers, trainees, trainers and other experts). These experiences will be utilized in our future studies.

Analysis of the preliminary use of our method is under investigation. The method will be applied to other process control areas, too. The operative context will be extended to comprise not only decision making in disturbance situations but also normal routine work in process control. According to our current expectations, differences in operators' orientation are reflected in their action strategies during normal work.

5 REFERENCES

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