Applying functional modeling for accident management of nuclear power plant

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Abstract: The paper investigates applications of functional modeling for accident management in complex industrial plant with special reference to nuclear power production. Main applications for information sharing among decision makers and decision support are identified. An overview of Multilevel Flow Modeling is given and a detailed presentation of the foundational means-end concepts is presented and the conditions for proper use in modelling accidents are identified. It is shown that Multilevel Flow Modeling can be used for modelling and reasoning about design basis accidents. Its possible role for information sharing and decision support in accidents beyond design basis is also indicated. A modelling example demonstrating the application of Multilevel Flow Modelling and reasoning for a PWR LOCA is presented.

Keyword: accident management; functional modeling; model based reasoning

1 Introduction

Recent investigations of the Fukushima Daiichi accident identified needs for improving the emergency response system in Japan including the overall organizational structures, procedures and tools[1]. The course of events at Fukushima shows that lack of situational overview of individual human actors and organizations contributed to an escalation of the immediate effects of the earthquake and the following tsunami into a large scale accident. The lack of overview was partly caused by the loss of plant instrumentation due to power failure caused by the tsunami, and by the partial failure of systems provided for monitoring the physical environment.

The lack of on-line “facts” about the event and its near term effects and consequences was obviously a source of considerable uncertainty in planning responses to the Fukushima accident. But independent of the lack of online information, plant accidents beyond design basis will introduce another level of uncertainty influencing decision makers and operators situation awareness. In such situations emergency procedures may be invalid because plant behavior has changed, the means of plant control may be lost, or the plant should be operated according to objectives different from anticipated during plant design. Even if the plant instrumentation survive an accident, it can therefore be difficult for operators to respond properly to the situation. Suggested means of improving situation awareness in accidents are information sharing and integration as well as computerized decisions support systems.

The purpose of information sharing and coordination is to ensure that decision makers on the plant site and its environment are well informed about the situation. Each decision maker need information relevant to his/her view point or task. And the different viewpoints should be integrated so that each decision maker sees his own task in the context of a shared understanding of the situation. Integration can be obtained by using common explicit plant models in communication between decision makers. Lack of information sharing and coordination among decision makers contributed to an escalation of the Fukushima Daiichi accident.

Decision support systems can also play a significant role in in the management of accidents by providing facilities for data acquisition and interpretation, evaluation of operational goals, and planning and execution of counteractions. Of particular interest is

Received date: November 4, 2014

to use model based systems and simulation where incompleteness and uncertainty of facts about the situation is reduced by using plant models. The models are used to estimate information not directly available from the instrumentation or expert judgments, to assess system states and operational situations and to propose counteraction plans[2].

One of the challenges in the Fukushima Daiichi accident was to find new ways and means for cooling the reactor which were not contemplated or deemed necessary by the designers. Another challenge was to provide countermeasures preventing releases of radioactivity from the plant caused by failures of safety barriers. Decision support systems may have been used to meet these challenges in state identification and evaluation of possible courses of action.

2 Multilevel Flow Modeling

Multilevel Flow Modeling (MFM) developed by Lind and coworkers[3] has been proposed by several researchers to be used for both information sharing and coordination as well as for decision support. MFM is a methodology for functional modeling which has attractive features for modelling complex systems. The main features are 1) MFM represent systems and their interactions on several levels of abstraction, 2) MFM support cause-effect reasoning, 3) MFM provide formalized representations of operational situations and 4) MFM concepts are coherent with human cognition. These four features are important when coping with operational problems in safety critical systems such as specification of operational situations, identification of causes and consequences of failure, situation assessment, derivation of counteraction plans and ensuring effective communication between decision makers and decision support systems. Lind[3] gives an overview of the present status of MFM and its applications within a range of industrial processes including a comprehensive list of references.

2.1 The basic MFM concepts

MFM represent goals and functions of process plants involving interactions between flows of material, energy and information. Functions are represented by elementary flow and control functions interconnected to form functional structures representing a particular goal oriented view of the system (Fig.1). The views represented by the functional structures are related by means-end relations and comprise together a comprehensive model of the functional organization of the system.

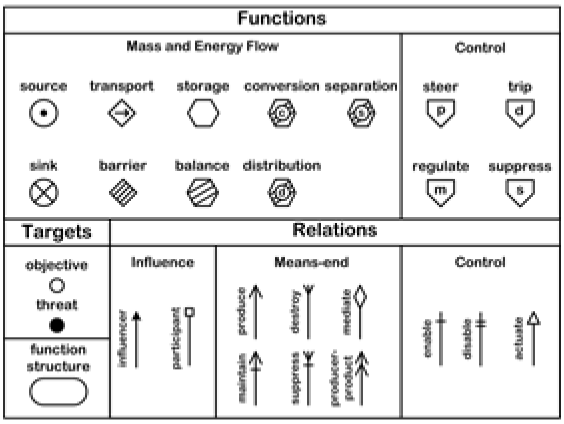

Fig. 1 MFM concepts.

2.2 MFM applications and methodology

Here we will only introduce the basic MFM concepts and refer the reader to overviews[3][4] for more details about the modelling concepts and the MFM applications which have been considered for decision support in design and operation. However, we will here mention the use of MFM for information sharing which has not been discussed in the overviews. Three applications in this direction are reported in the literature. Yoshikawa.[5] present an MFM based integrated design and simulation environment to be used in sustainable energy and environmental systems for evaluation of alternative systems solutions. Gofuku[6] present the use of MFM for display of diagnostic information from multiple viewpoints in anomalous situation. Rossing[7] discuss the possible role of MFM in risk assessment for information sharing in a group of process experts.

Recent research has also considered methods and tools for building MFM models which are relevant for the theme of the present paper. Heussen[8] discuss the need for a methodological approach and for tools to support the construction of models of complex systems. The aim is here to develop a stepwise approach and to reduce the model building effort and to improve quality by using a model library of design patterns. Wu[9] propose a methodology for validation of MFM models for Hazop. Model validation is a critical issue in general when using MFM for handling accidents both within and beyond plant design basis.

2.3 MFM and operational failures

MFM has accordingly been used for modelling a significant number of different processes and used for both diagnostic and planning applications. However, most of the applications of MFM presented in the literature are related to operational situations which are considered by the system designer i.e. where the system is assumed to behave according to its intended purpose. In MFM operational failures are seen as deviations from intentions, and causes and consequences of failure are derived from the means-end relations and causal influence relations between functions represented by the MFM model. Failure causes which are not deviations from intentions are only considered to the extent that they are deviations from operational preconditions necessary for realization of intentions. These failure causes and consequences derive from enablement relations in MFM (Fig.1).

The MFM models presented in previous studies are accordingly considered for operational situations which are within the design basis. In the following we will demonstrate by examples that design based accidents can be handled by MFM. But accidents beyond design basis like the one at Fukushima Daichii happen and it is unclear how MFM models can be used to cope with these accidents and still satisfy the basic principles of the modelling methodology. The main purpose of the remainder of the present paper is to investigate these issues by an analysis of the underlying modeling assumptions for MFM.

2.4 MFM modeling assumptions

Some of the basic assumptions in functional modeling (and therefore MFM) are general and shared by other types of modelling such as *e.g.* differential equations. But another set of assumptions are specific for MFM and derived from the foundations of functional modelling in means-end concepts and reasoning. Both the general and the specific assumption are relevant for modeling accident situations within and beyond design basis.

We will deal with the two types of assumptions separately below. The general issues will be addressed by the model relation proposed by Rosen[10]. The issues specific to MFM will be addressed by a discussion of the means-end concepts which are foundational to MFM and by presentation of preliminary results from ongoing research by one of the authors (Zhang) on modeling LOCA in a Westinghouse type PWR. Since the modelling examples are from a PWR the conclusions of the study may not be directly relevant to the specifics of the BWR reactors at Fukushima Daiichi. However, we believe that the modeling lessons drawn from the examples are of a generic nature and would be applicable also for BWR plants.

3 The model relation

Rosen used the model relation shown in Fig. 2 for discussing the roles of models in natural science. We have adapted the model so that it applies to modeling in engineering sciences. The main difference being that the object of modelling in engineering is an artifact with both physical and social features and not only a natural object.

The model relation represents fundamental relations between the object of modelling (here the artifact) and the model which is a formalized representation of artifact properties which can be used for inference or simulation. The encoding relation is essential and refers to the active process of model building. Furthermore the decoding is a translation of inferences or the model into physical action for control or the implementation of an object represented by the model.

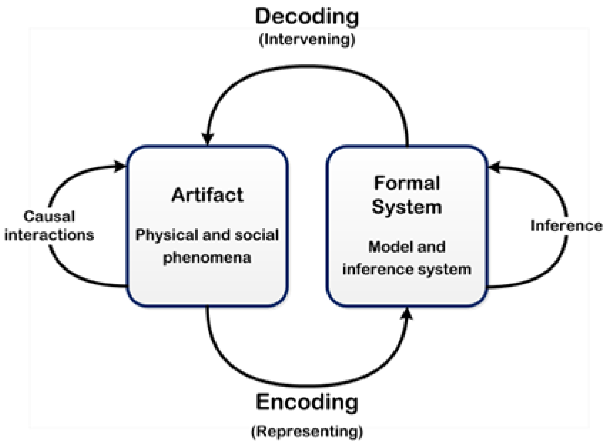

Fig. 2 The model relation (adapted from Rosen[10]).

3.1 The role of experience for modeling

Models and the inferences we make from them are fundamentally based on experience such as observations, operational experience and first principles generalizing from experimental evidence. The purpose of encoding in Fig. 2. is to make the experience available in a formalized form so it can be used for inference. This means that modeling is based on situations we have experienced or can anticipate, for example the situations considered in design based accidents.

Using models to make inferences about unanticipated situations as encountered in accidents beyond the design basis is therefore problematic. There are three ways to deal with this problem; 1) models based on first principles can cover a wide range of situations which may go beyond previous experience, 2) models can be simplified so that they become robust and give useful but less accurate responses in a range of situations, 3) model building can be seen as a dynamic process where previous experience and models are adapted to the new situation.

Unanticipated situations can accordingly be handled in some situations by robust models based on previous experience (1 and 2 above). But in some situations a model should be constructed in the situation as a means of making sense of observations and other evidence. In such cases the model is used in problem formation and can subsequently be used for problem solving (3 above). The importance of this distinction between problem formation and problem solving is emphasized by Schön[11] who claims that professionals when they solve complex problems also are engaged in a reflection with the situation in order to frame the problem i.e. to construct a model which can be used to solve it.

MFM can be used in anticipated situations as long as the basic assumptions for using means-end concepts are satisfied (see later). MFM support also the three ways of dealing with unanticipated situations. The models are based on first principles (1) because the basic flow concepts for modeling process functions are qualitative representations of the principles of mass and energy conservation. As we shall see below, MFM models are also robust (2) because models can be formulated on several levels of abstraction. Finally, we see a possibility for developing a methodology and tools for model building and validation which can be used dynamically during the problem formation phase (3).

4 Foundational issues in MFM

MFM and functional modeling in general is based on means-end concepts and we will explain the underlying assumptions behind their proper use.

4.1 The means-end relation

The concepts of means and ends have many meanings in their common use. An end can for example be a state to be obtained or could be the performance of an activity. A means could for example be an object, a tool, a procedure or an action. But being a means or an end depends on the context. An item which is considered a means (for an end) in one situation can in another situation be considered an end (for a means). Being a means (or an end) is accordingly not an inherent property of an item or a situation but depends on whether it enters into a context of something which is considered an end (or a means). Means and ends should accordingly be seen as defined through a relation.

The means-end relation is depicted as shown in Fig. 3 as a vertex connecting two nodes. The means and the end are the terminals of the relation. The nodes at the terminals become in this way a means (P) and an end (Q) by being related. The means-end relation is here considered as an abstract concept representing generic properties which are common to the more specific and expressive types of means-end relations which are used in e.g. MFM (Fig. 1).

Fig. 3 P is a means to the end Q.

The means-end relation is in MFM seen as having four aspects: structure, behavior, function and goal aspects with corresponding distinctions between types of means-end relations. These distinctions will be ignored here in order not to complicate matters to much.

4.1.1 Semantics of the means-end relation

The means-end relation implies a semantic network of underlying conceptual relations between means, ends, purposes, intentions and experience. A means-ends relation and its associated nodes express information about purposes since the purpose of the means is to produce or maintain the end. Means-end relations are therefore, through the associated purpose, expressions of the system designer or another agent's intention. The intention to use the means for the end is motivated by the agent by his previous experience. This experience includes knowing how the plant behaves in different situation and the means which have been used before successfully to accomplish operational goals.

This can also be expressed by two aspects of the means-end relation. When P is a means for an end Q it is clearly implied that P should be used by an agent with the intent of achieving Q. This is the *teleological* aspect of the relation. Furthermore, P should also be able to produce the end. This *causal* aspect of the means-end relation is connected with the agent's experience – that the means can cause the end. P cannot be a means if it is not both defined with the end in mind and able to produce it. These are the preconditions for P and Q being related by a means-end relation. These preconditions are foundational to functional modeling. If they are violated the models cannot be used for reasoning about means and ends.

4.2 Means-End structure

The means-end relation can be used to create means-end structures by three main principles for structure creation; 1) means and ends can be connected into chains, 2) means-end structures can be contracted or expanded to create more abstract or more detailed structures and 3) means and ends can be related by many to many mappings. These three principles are rooted in our common sense understanding of means-end concepts. They are foundational for MFM and will be explained in some detail below.

4.2.1 Chains of means and ends

The connection of means and ends into chains are exemplified in Fig. 4. The principle is straight forward because an end often is the means for another end and is well known *e.g.* in the design of plans of action. Here the result (end) of an action often will be a precondition (means) for the execution of another action.

It is always possible to identify further ends and more primary means and a chain of means and ends can apparently be extended without limits in both directions. The connection of means and ends in chains raises therefore a fundamental question regarding the existence of ultimate means and ends. But in the current context of design and operation of industrial systems means will always be selected from within a set of possible practical options given by the situation and not derived from more primary means (causes). Furthermore the effect of a applying a means in a situation will always be defined in relation to the result intended (the end) and not to more ultimate ends. The lengths of the chains of means and ends will accordingly be limited in practice by what is considered relevant for the problem at hand or point of view.

The means-end relation is transitive so that if P is a means to the end Q, which again is a means to another end R, then P is a means to the end R. The transitivity of the relation therefore enables contraction and expansion of a chain of means and ends as illustrated in Fig. 4.

The transitivity of the means-end relation is a very desirable property because it allows changes of the level of abstraction *i.e.* ignoring details which are irrelevant for the problem at hand or adding details when required.

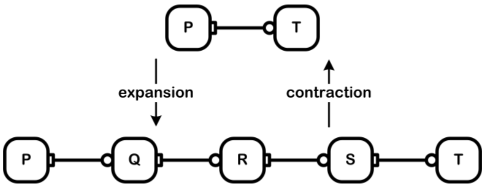

Fig. 4 Means end relations form chains which can be expanded or contracted.

The concepts of means and ends and the associated relation are not entirely sufficient for modeling safety critical processes like NPP’s. They do not apply for situations which involve some sort of threat as the target of action. Such targets are rather to be seen as not-ends because the purpose of the action is to prevent them from being realized. Furthermore, we refer to actions, procedures or things used to avoid or suppress threats not as means but as countermeasures. This relation between a threat and its associated countermeasure has a teleological aspect as the means-end relation as well as a causal aspect since the effect of the countermeasure (the cause) is that realization of the threat is avoided.

Ends and threats belong to the set of possible future situations but they do not make up the whole set. Future situations also include situations the agent does not care about. These situations are neither desirable (the ends) nor undesirable (the threats). This means that we cannot treat threats as the logical complement of the ends i.e. as "non-ends" since the set of non-ends would, in addition to the threats, include the situations the agent do not assign any value. In the following we will not distinguish the means-ends and the countermeasure-threat relations.

4.2.2 Many to many mappings

Above we have considered the means-end relation as a binary relation but means and ends are in fact in general related by many-to may mappings. Two mapping directions are distinguished corresponding to the teleological and the causal aspects of the relation.

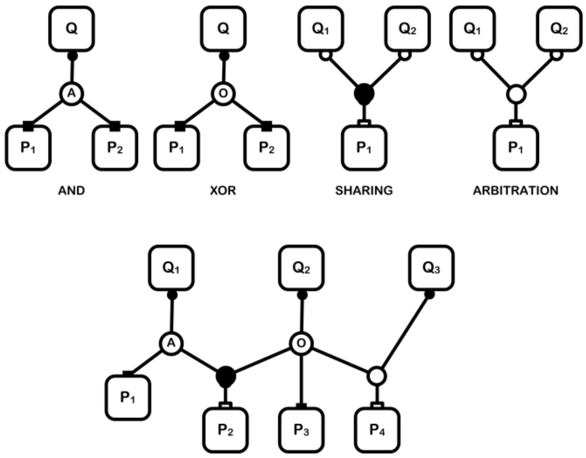

Fig. 5 Many to many mappings between means and ends by AND, OR, sharing and arbitration relations.

The same end can often be realized by several alternative means or require several means for its realization. This mapping from ends to means can be expressed by extending the vertex representing the means-end relation with an AND/OR graph notation as shown in Fig. 5. The AND/OR branches can be seen as a decomposition structure for the ends and should be read from the end (round dot) towards the means (square dots). The AND/OR combinations of the means are accordingly derived from the teleological aspect of the means end relation i.e. the end determine or constrain the combination of means.

Sometimes a means can be used to realize several ends at the same time, or it can only be used for one end at a time. These conditions are also shown in Fig. 5 as extending the means-end relation with sharing/arbitration nodes [12]. The branches in these structures which should be read from the means (square) towards to the ends (round) represents causal constraints *i.e.* the effects (ends) which can be obtained at the same time by the same means (cause). The means determine or constrain accordingly the combination of ends.

Means and ends are therefore connected by many-to-many mappings as illustrated in Fig.5 and form heterarchies as shown in Fig. 6.

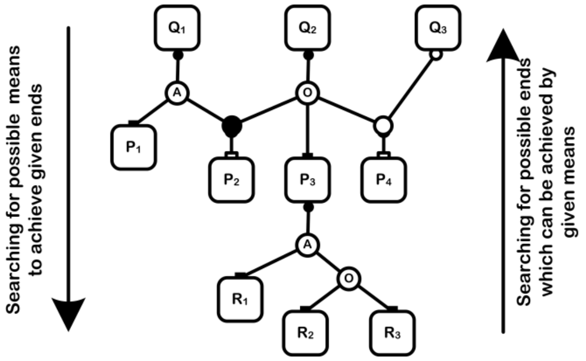

Fig. 6 A heterarchy of means and ends and its support for reasoning about means-and ends.

4.3 Means-end heterarchy

The means-end heterarchy can serve as a framework for problem solving in redundancy management. The heterarchy show the alternatives available in a given situation and can be used for reasoning about which of the alternatives to choose. It may also be used for risk monitoring by assessing the risk of losing resources. More complex structures can be created by combining many to many mappings with the chaining of means and ends. These structures will in general be forming heterarchies (hierarchy with more than one top node).

4.4 Modes

The means-end structure shown in Fig. 5 defines different exclusive ways to realize the ends Q1, Q2 and Q3 by means of P1, P2, P3 and P4. Each manner or way of realization (here three) define a mode which is represented by a means-end structure as shown in Fig. 7. Modes are accordingly represented by specialized means-end structures without OR or arbitration nodes.

Modes represent means and ends which are available at the same time. In contrast, a heterarchy represents means and ends which are not available at the same time (the exclusive OR and the arbitrations). Mode structures support cause and consequence reasoning about operational failures. All MFM models presented in current literature are single mode structures except the study of modes of normal operation for the MONJU reactor presented by Lind[13]. Below we will show that modes also can be used to model stages in the development of a LOCA in a PWR. Transitions between modes are in both cases caused by control actions.

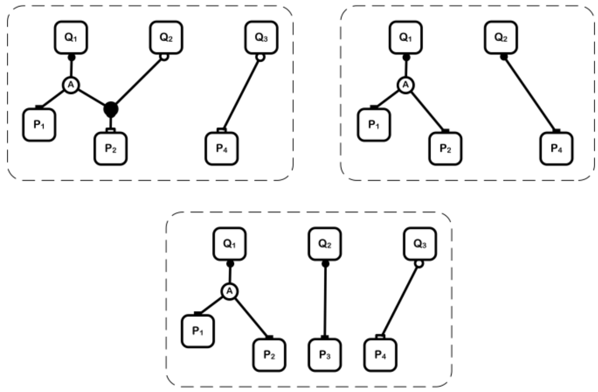

Fig.7 Three modes derived from the means end structure in Fig. 5.

4.5 Summary

In summary we can accordingly conclude that the means-end concepts, when used according to the underlying assumptions mentioned above, can serve as a framework for decision making and control of operational disturbances and accidents. This includes:1) deviations from normal operation, 2) transitions between normal modes of operation, 3) accidents which are anticipated and therefore accounted for in plant design (design based accidents) and 4) accidents which are not anticipated and which ultimately can develop into emergencies (accidents beyond design basis). Note that these three challenges to plant operation relate to levels of defense in NPP and comprise subsequent phases in the development of an accident. The main strength of the means-end framework is that it provides an effective basis for both reflection (problem formation) and systematic reasoning (problem solving).

5 Modeling LOCA in a PWR

Accidents anticipated by the designer are usually handled by countermeasures which has the purpose to suppress or eliminate threats to the operation or safety or to ensure that the plant enter in a safe state. As indicated above, such means and (non) ends can be represented in a means-end framework and therefore be used to develop models which can be used to cope with accidents both in the design phase for risk assessment and online in computerized systems for decision support. The challenges are here to develop MFM models for the phases of the accident including the automated safety actions.

The coauthor of this paper (Zhang) is presently investigating the use of MFM for modeling LOCA using the Ringhals reactor simulator in OECD Halden as a case. Below we will describe some preliminary results from this study.

5.1 The MFM model

Three MFM modes will be presented. They represent the mass flow structures of the RCS during the evolution of a LOCA and comprise together a MFM model of the LOCA. Note that the models are simplified by excluding the energy functions supported by the RCS and the detailed functions of the circulation pumps.

A particular feature of MFM is a clear separation of plant components and functions. This means that the same component or subsystem may be represented by several functions and a function may be realized by alternative components or subsystems. These many to many mappings between means (components or subsystems) and ends (functions) were introduced earlier (Fig 5). The PWR model presented below includes several examples of many to many mappings between components and functions.

The separation of functions and components also influences how accidents are classified in MFM. Accidents situations are in MFM represented according to their functional consequences. Two accidents which are distinguished by the failed components or their location may have the same implication for overall mass and energy balances and their impact on operational goals plant and would therefore be represented by the same MFM model. The model shown below represents several accidents which usually are distinguished from a LOCA (leakage of steam generator and PRZ vessel). Conversely, a component or subsystem may have several modes of failure with different functional consequences. Such accidents are not considered below but would be represented by different MFM models, one for each failure mode.

5.1.1 MFM of RCS in normal operation

During normal operation, the RCS system can be represented in MFM by the model shown in Fig. 8. The storage function sto_reactor represent the storage of water which is heated up in the reactor vessel. The function tra1 represents the transportation of water from the reactor to the steam generator which is represented by the storage function sto_sg. The water is transported through the steam generator (tra3) to the coldleg represented by the storage function sto_coldleg, and further transported (tra2) back to the reactor vessel. Note that we have here an example of a one to many mapping between a component (the steam generator) and functions (tra3 and sto_sg) mentioned above. Note also that the coldleg is represented as the storage function sto_coldleg even though it is a pipe. This illustrates how MFM distinguish components and functions. The function describes what the component is used for in a particular goal context. Even though the coldleg is a pipe and accordingly could be seen as providing a transport function, it should accordingly be assigned a storage function if used for that purpose.

The transport function tra3 represents the reactor coolant pump that controls the flow in the RCS. The bidirectional flow of water in the pressurizer surge line is represented by tra4 and tra6, and tra5 represent the transport of water in the spray line. The accumulation of water and steam in the pressurizer is represented by the storage function sto_prz.

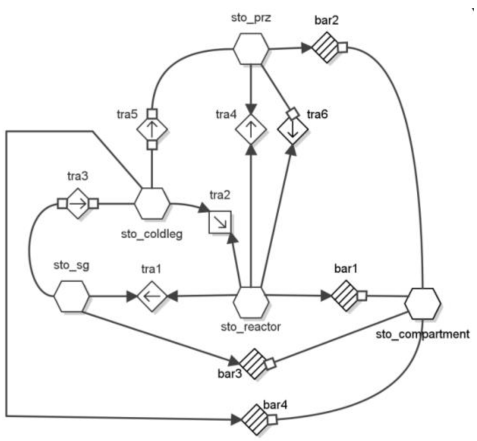

Fig. 8 MFM mode of RCS for normal operation.

The mode includes also the barriers bar1, bar2, bar3 and bar4 which separate the containment building from the RCS. These barrier functions are included by the plant designer to prevent cooling water from leaving the RCS. These functions are only relevant to include when considering safety critical situations as a LOCA where the reactor coolant is lost.

5.1.2 MFM with barrier failure

The mode in Fig. 9 represents the situation where bar1 has failed. In a LOCA any of the barriers bar1, bar2, bar3 and bar4 can be failing (leaking). The barrier failure can be detected with the existing MFM reasoning system and it is assumed that the model has been changed (bar1 to a transport function tra7). This mode then represents the system in the initial phase of a LOCA. Note that it is assumed that the reactor vessel implementing the barrier functions fail in a way so that the barrier is substituted by a transport function. This may seem to be an unnecessary assumption but it is required in order to ensure consistent use of the means-end concepts (and the vessel may actually fail in other ways not intended). The new MFM mode in Fig.9 can be used to make a qualitative consequence analysis of what happens after the barrier failure during a LOCA. Note that causes of barrier failure and its substitution by a transport function cannot be inferred from the present MFM model since it does not include information about the relations between structure and function.

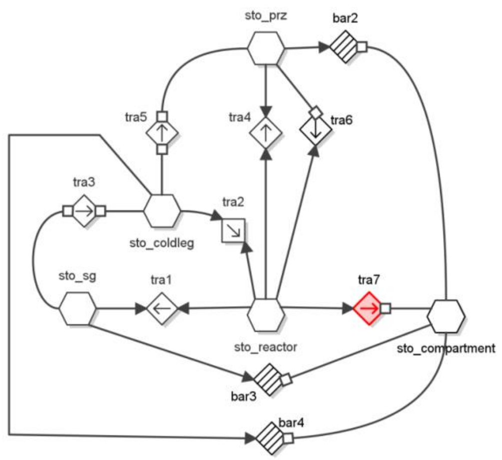

Fig. 9 MFM mode at the onset of the LOCA.

If we assume that bar1 is failing a water path from the reactor vessel (sto_reactor) to the containment building (sto_compartment) will be established. As a consequence the volume of coolant will decrease in the RCS primary circuit. But the pressure drop (related to the energy balance model not included here) will trigger a safety action which changes the mass flow structure shown in Fig. 9 to the structure shown in Fig. 10. This transition is actually a mode change reflecting the consequences of actions of the safety system. The mode change is intended by the plant designer as a countermeasure against the threatening loss of cooling situation. After the intervention by the safety system, the system will automatically draw cold water from the cold leg collector and the safety injection pumps will start to operate and pull more cold water from the reactor water storage tank (RWST). The transport functions tra8 and tra9 are accordingly established as shown in Fig 18. When the volume of water in the RWST (sto_rwst) drops to zero, another water path will be established in order to recollect the leaked coolant from the containment building. This is represented by tra10 in Fig. 10.

We can accordingly conclude that MFM is able to represent phases of a LOCA accident including the consequence of safety actions. At moment the model does not include the functions of the safety system. The mode in Fig. 10 represents only the consequences of the safety actions for the mass flow structure. The study shows that the mode concept can be used to model the (intended) development of a LOCA.

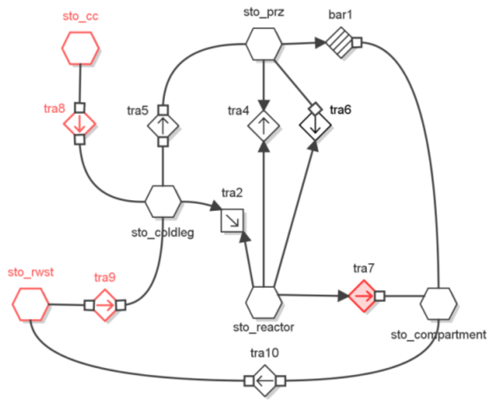

Fig. 10 MFM mode after the safety intervention.

Gofuku[14] present another study demonstrating the use of MFM for reasoning about an accident with loss of heat sink. In this study MFM is used to reason about alternative heat sinks. Here the ability to change level of abstraction in MFM is demonstrated.

5.2 Discussion

Modeling accidents situations is a new direction of research in Multilevel Flow modeling. The PWR LOCA model is a first demonstration showing that MFM can be used for this purpose. But as discussed above, the proper use of MFM is conditional on a set of general assumptions (stated in section 4.1.1). These assumptions are not tested here so we cannot claim that the model is a valid MFM model. Validation methods for MFM are under development by Wu *et. al*.[6].

How to use MFM models for accident management is also a topic of further investigation. The present paper show that MFM can be used discriminate the different phases in the development of an LOCA. MFM provides in this way a formalized way of defining overall system states. Each of the models representing a particular overall plant state can be used by the existing MFM methods for cause-consequence reasoning. However, methods for mode identification do not exist yet and needs therefore to be developed.

It is clear that the development of a MFM based system for management of design basis accidents require a significant modeling effort in identifying modes and mode transitions and building the corresponding MFM models. However, the model building tools available including the planned extensions with model libraries enabling model reuse will reduce the development time considerably. In return for this engineering effort MFM and its associated reasoning tools will offer a robust framework for formalized definition of system states, operational modes and associated rules for reasoning about design based accidents.

Using MFM to manage accidents beyond design basis raises new significant research issues for future consideration. The most challenging problem is to compensate for the lack of experience in such situations, which means that there is no available library model or sub-models which directly apply in the situation. What is required is a methodology for constructing an MFM model which makes sense of a situation. Such a methodology would in addition to a library of modelling cases and MFM syntax rules, also rely on evidence from instrumentation, plant operators and other experts.

6 Conclusions

The paper has investigated applications of functional modeling for accident management in complex industrial plant with special reference to nuclear power production. It is concluded that functional modelling can be applied for information sharing among decision makers and decision support. An overview of Multilevel Flow Modeling is given and a detailed presentation of the foundational means-end concepts is presented and the conditions for proper use in modelling accidents are identified. It is concluded that Multilevel Flow Modeling can be used for modeling and reasoning about design basis accidents. However, the use of MFM for information sharing and decision support in accidents beyond design basis is not fully explored and requires more work. A case demonstrating an application of Multilevel Flow Modelling and reasoning for a PWR LOCA is presented.

The conclusions regarding the applicability of functional modelling (MFM) for coping with abnormal operating plant situations are made by considering the foundational concepts of MFM. The conclusions are therefore believed to be valid in general with regard to the use of functional modelling in coping with accidents. The actual relevance of the conclusions for various aspects of the recent accident in Fukushima Daichii has not been investigated. The reports made available for the public are not sufficient for this kind of work. It will require involvement of experts with deep insights in the Fukushima Daiichi plant and the specific nature of the operational problems occurring in the various phases of the accident. The conclusions are only applicable for accidents management within the power plant.

Acknowledgement

The work was supported by the Chinese 111 project on Nuclear Safety and Simulation hosted by CNST at Harbin Engineering University, and by the IFE OECD Halden Reactor Project in Norway through the cofunding of Xinxin Zhang's PhD project.

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