Session 3

## EXTENSION AND NEW CONCEPTS OF C&I SYSTEMS

Chairman

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# EXTENSIONS AND RENOVATIONS OF REACTOR PROTECTION SYSTEMS

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### Abstract

Increase of requirements by the authorities as to the design of reactor protection systems affected in the last years not only plans being under construction, but also resulted in partly spacious extensions and renovations. While working on the extensions and renovations a lot of problems arose: - far-reaching performance of newest guidelines and rules in spite of old plant concepts; - partly higher degree of redundancy requirements of the new systems in contrast to the present systems; - use of present safeguard systems for new accident countermeasures; - designation of priorities between present and new functions, especially in view of fault behaviour of present systems; - adaptation of the new I&C equipment to the present signalisation-, operation- and information-arrangements under consideration of the present operational philosophy; - spatial incorporation of new equipments; - construction as to time without expanding of the planned refuelling phases. Because the KWU has planned and constructed such alterations in nearly 10 plants a lot of experience has been gathered.

The development of the pressurized water reactors (PWR) as well as of the boiling water reactors (BWR) from the first commercial operating plants till today shows a continuity in the development of accident considerations and in the structure of the safety systems. Therefore the efforts, to accomodate the plants with older status to the actual status at time, could be successfull.

10 So in the recent years a lot of extensions and renovations of reactor protection systems have been planed or constructed respectively will be designed, of which the Kraftwerk Union is participarting especially in that plants which have been constructed by themselves with extensive lay-out performance and deliveries.
A review about this activities is shown in Fig. 1 in which you can find the PWR and BWR plants constructed by Kraftwerk Union and which are under operation since now.

A global impression about the scope of the extensions is derivable from the number of additional reactor protection cabinets.
But too in relationship with planed extensions of safety countermeasures in nuclear power plants of other manufacturers there have been realized a lot of design performances, e.g. for the NPP Beznau and Mühleberg in Switzerland.
After this common overview about there activities in connection to extensions and renovations of reactor protections systems in the following special problems at the example of PWR's shall be discussed.

At the beginning I like to give you a definition of the reactor protection system, as it is in use in Germany. The important safety-related lay-out fundamentals for the reactor protection system are stated in detail in the KTA rule 3501 which complies with many international guidelines. In this rule the following definition is met:

> "The reactor protection system is a system which monitors and processes the values of process vari- ables relevant to the safety of the nuclear power plant and the environment in order to detect incidents and to initiate protective actions so that the condition of the nuclear power plant is kept within safe limits."

The reactor protection system includes - according to German interpretations - equipment for actuation of reactor trip and engineered safeguards (see Fig. 2). The important engineered safeguards for PWR are

- the residual heat removal
- the containment isolation
- the extra borating
- the emergency feedwater supply
- the relief station
- the emergency power supply

Since the reactor trip actuation is done by a lot of initiation criteria in older plants too, the backfitting measures refer mainly to engineered safeguard systems.
In the following Fig. 3 reasons are listed up for extensions and renovations of reactor protection systems.

From technological views the following aspects led to extensions of reactor protection systems

- extended accident considerations refering to the TMI accident
- extended accident considerations refering to steam generator heating tube leakages
- erections of additional emergency systems against external events

and as a clear aspect of instrumentation and control devices

- renovation of old reactor protection equipment

The consequences of the 3 technological aspects on the safeguard systems are shown in detail in Fig. 5.
As a consequence of the TMI accident mainly the following measures were executed

- automatical cool-down of the primary coolant with 100 K/h via the main steam relief station
- automatical isolation of the accumulators
- additional feedwater supply of the steam generator by emergency feed systems.

To improve the accident countermeasures in case of steam generator heating tube leakages the following countermeasures were extended, which additionaly are effective for accidents by external events:

- automatical controlled partial cool down via the main steam relief station, that means analog control of the main steam pressure on a value below the set point of the main steam safety valves with the task to hinder a repeated actuation of the safety valves

- Isolation of a fail opened safety valve with the consequence of steam generator heating tube leckage and release of radioactivity to the environment.

This countermeasures will be actuated by accidents following external events to avoid steam generator heating tube leckages.

The additional countermeasures for external events as
- emergency feedwater supply
- emergency power supply

replace safeguard systems which are not secured against external events but this systems will be additional redundancy for internal accidents.

The improvements refering to the main steam relief station and the accumulators are an automation of formerly manual measures.

The glance into the technological modifications in relationship to extensions which was given in the first part of the lecture was nesessary for a better discussion of the problems of I+C extensions and modifications which are mainly refering to structures and organisation of reactor protection systems. First of all the extensions of existing reactor protection systems respectively the erection of additional reactor protection systems was a result of extended automation of accident countermeasures in the actuation level.
An extension of the initiation level for existing countermeasures was realized only in exceptional cases and can be realized as backfitting measure without special problems, because there is no influence on structures and organisation of reactor protection systems.

Modifications and extensions only refer to reactor protection equipment, but not to switch gears and safeguard components.

But extensions in this field leads to problems relative to the erection of additional equipment, because of the collaboration of old and new systems as well in the safeguard systems as in the safety I+C systems has to be perfectly and necessitates priorities. These problems are shown in Fig. 4.

In the following cases the erection of independent reactor protection systems is possible:

- if for the additional countermeasure independent safeguard system or indipentend safeguard components are foreseen. In the design phase it should be considered to use no components for new countermeasures, which recieve already commands from an existent reactor protection system.

- if this is not possible it should be prefered to have the same direction for the commands of the existent and the new reactor protection system.
  In this cases only I + C problems in collaborating of the commands of two different equipments could arrive, but a special priority control is not necessary.

Is such a solution not possible, but is it necessary to control a component by the existent respectively by new erected reactor protection systems into opposite positions, the erection of new equipment is only possible, if there are determined clear priorities.

The greatest requirements arise, if countermeasures against external events have to be erected but commands of an existent reactor protection system have to operate on the same component. If the existent reactor protection system is remaining in that area which can be destroyed by external events the regulation of the priorities is necessary in that way that the commands of the reactor protection system which is located in an area secured against external events have the higher priority.

If such a priority is inadmissable for internal accidents, it remains no other possibility as to renovate this countermeasure in the new reactor protection system in the secured area to have a protection against spurious initiation.
The consequence of this transfer is, that the degree of redundancy of the new reactor protection system in minimum the same as of the existens system. This can result into a lot of consequences in the design of the additional reactor protection system, because all requirements for the existent system have to be fulfilled by the new system too, although the requirements for the new additional countermeasures are smaller.

This problems shall be discussed more in details by the example of KKU (NPP Unterweser), especially illustrated by conderations of external events and the main steam relief station.

The original layout during the construction of the plant provided no special systems to control accidents by external events. Correspondingly the actuation of 4 x 50 % safeguard system was done by a four fold redundant reactor protection system A (signed with the redundancies A1 + A4 in Fig. 6) which was located in the switch gear building.

A main steam isolation, which was necessary for some internal accidents was actuated by the reactor protection system A (redundancies A1 and A2 of steam generator 1). The secondary side heat removal was realized by the safety valve of the relief station, because of relief control valve and the relief gate valve were closed by main steam isolation signals from the reactor protection system. As a long time measure the gate valve had to be opened by manual command and the control valve actuated for controlled pressure limitation.

In a second layout phase, which was still realized during the plant contruction, an additional emergency feed system for protection against accidents by external events was erected, which includes a second independent reactor protection system B, consisting of the redundancies B1 and B2 (Fig. 7).

This system was erected with spatial separation from the reactor protection system A, so that in the case of an external event only one of the both systems could be destroyed. Because of the systems inside of the reactor building and the relief station could not be destroyed by external events, the heat removal could be done by emergency feed and the relief station.

For main steam isolation by the reactor protection system B in the case of external events the mainsteam isolation valve recieved additional solenoid valves and additional control commands B1 and B2 from system B. Besides the control valve recieved an additional gate valve with the control command B1 from system B. The heat removal after main steam isolation was ensured by the safety valve.

According to this technological advices it was possible to erect 2 independent reactor protection systems.

In a second phase of KKU-backfitting which will be designed at time, improvements of accident countermeasures against steam generator heating tube leakages shall be provided.
It is postulated that in the case of steam generator heating tube leakage in coincidence with loss of power supply a safety valve of the relief station remains in the open position (see Fig. 8).
For control of this accident an additional gate valve in the steampipe to the safety valve is foreseen, which shall be closed in the case of an open remaining safety valve.

The pressure limitation will be done by the relief control valve, with an analog controller which will be actuated by high steam pressure and control the steam pressure to a valve below the setpoint of the safety valve.
This contermeasure originally is necessary for an internal event. Because of spurious signals from the reactor protection system can influence countermeasures for external events in a not tolerable manner it is necessary to place this equipment into a building secured against external events. Therefore the reactor protection system C with the redundancies C1 ... C4 is foreseen for this KKU-backfitting phase. So the reactor protection system C is an integrated system which fulfills tasks for accidents initiated by internal and external events.



The upper explanations showed that the technological concept is very important for the problems and solutions of the design of extensions and modifications of reactor protection systems.

At the end let me do some remarks about special I + C views.
As already mentioned before, for some backfitting solutions it is necessary, to build priorities between seperate reactor protection systems and to have a protection against spurious initiation. For these aspects KWU developed special electronic circuits.

The organization of additional safety related I + C is shown in Fig. 9

Priority modules are attached to the control interface of pumps and valves, which connect signals with different priorities from various reactor protection system or other safety related I + C equipment.
Additionaly they allow manual commands either from the main control room or an emergency control room, depending on a selection switch.

The priority modules insure that for example in case of external events the necessary countermeasures from a secured reactor protection system and necessarily following up manual commands from the emergency control room can be executed without influences of the destroyed parts of the plant.
Manual interventions into the reactor protection system, for example commands for bridgings or memory reset are secured against spurious signals by a special coded release. This release is a binary coded signal which cannot be fail actuated by external events with a very high probability.

An other advantage of the organaization of I+C backfitting measures shown in Fig. 9 is, that the erection and the start up of the additional equipment can be done during normal plant operation.

106 Only the insertion of the existant reactor protection and normal operational commands into the prepared de-coupling and signal accommodation interface is necessary during shut down phases. This can be executed in a very short time, for instance during refueling.
Short interuptions of normal operation should be one main layout aspect for extensions and renovations.

As conclusion it can be confirmed that extensions and renovations of reactor protection systems require the clearification of a lot of problems which can lead to very different solutions, but which depend in a great manner on technological improvements and postulated conditions of the accident philosophie.

Experiences with plants which started again for a longer time with important extensions and renovations show that backfitting measures can be executed in short shut down phases and with positive consequences for the following plant operation.

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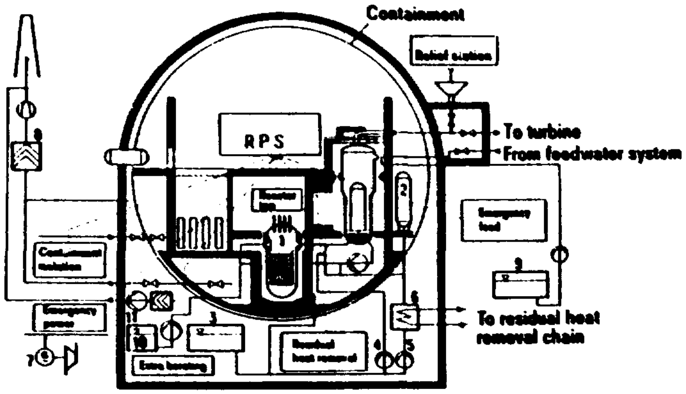
| | KWU plants | date of commissioning | KWU scope of RPS-cabinets |
|---|---|---|---|
| PWR | KWO Obrigheim | 1968 | ≈ 16 |
| PWR | KKS Stade | 1972 | - |
| PWR | KCB Borssele (Netherlands) | 1973 | ≈ 7 |
| PWR | Biblis A / B | 1974/76 | ≈ 7 |
| PWR | GKN 1 Neckarwestheim | 1976 | ≈ 4 |
| PWR | KKU Unterweser | 1978 | ≈ 20 |
| PWR | KKG Gösgen (Switzerland) | 1979 | - |
| PWR | KKG/BAG Grafenrheinfeld | 1981 | - |
| BWR | KWW Würgassen | 1972 | ≈ 15 |
| BWR | KKB Brunsbüttel | 1976 | ≈ 20 |
| BWR | KKI Isar | 1977 | ≈ 1 |
| BWR | KKP 1 Philippsburg | 1979 | - |

Scope of RPS extensions by KWU

Fig. 1




1 Reactor trip system
2 Accumulator
3 Borated water storage pool
4 Safety injection pump
5 Residual heat removal pump
6 Residual heat exchanger
7 Emergency power system
8 Vent system
9 Emergency feedwater system
10 Boric acid storage tank
11 Annulus air extraction system

RPS Reactor Protection System

▭ TMI consequences

▭ steam generator heating tube leakage

▭ external events

**Engineered Safeguards (Schematic)**

Fig. 2



## Technological aspects

- extended conciderations of accidents as a consequence of the TMI-accident
- extended considerations of accidents with regard to the steam generator heating tube leakage
- erection of additional systems for countermeasures against accidents by external events

## I + C aspects

- Replacement of old I + C systems by new one's with better reliability and test comfort

Reasons for Extensions and Renovations of Reactor Protection Systems

Fig. 3

| problem | consequence |
|---|---|
| control of independent systems<br>control of independent components | erection of independent reactor protection systems is possible |
| control of common components into the same direction | |
| control of common components into opposite direction | erection of independent reactor protection systems is only possible, if there are clear priorities between the reactor protections systems |
| suprious initiation is inadmissable (f. ex. as consequence of external events) | security against spurious initations by erection inside of secured areas |

Cooperation of existing and additional Reactor Protection Systems

Fig. 4

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| safeguard systems \ reasons | TMI consequences | Steam generator heating tube leakage | external events | improvements |
|---|---|---|---|---|
| main steam relief station | automatical cool down with 100 k/h of the primary coolant | automatical partial cool down steam pressure control to a value below the safety valve set point<br>isolation of a faulty opened safety valve | | automation of formerly manual countermeasures |
| accumulators | automatical isolation of the accumulators | | | |
| emergency feed system | additional feed of steam generators | | feed of steam generators | higher degree of redundancy for internal incidents |
| emergency power supply | | | power supply for additional systems | |

Technological Reasons of Reactor Protection Extensions

Fig. 5

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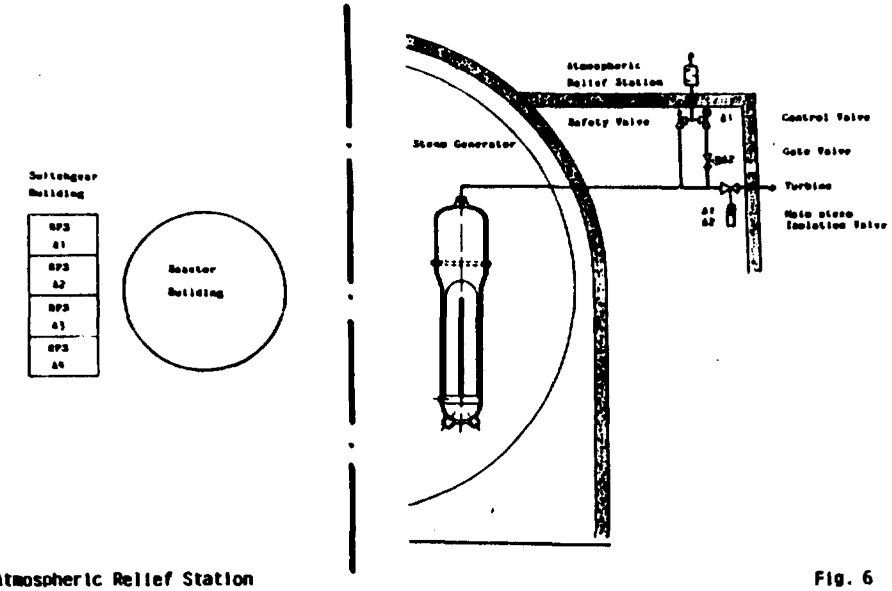


Atmospheric Relief Station Variant 1

Fig. 6

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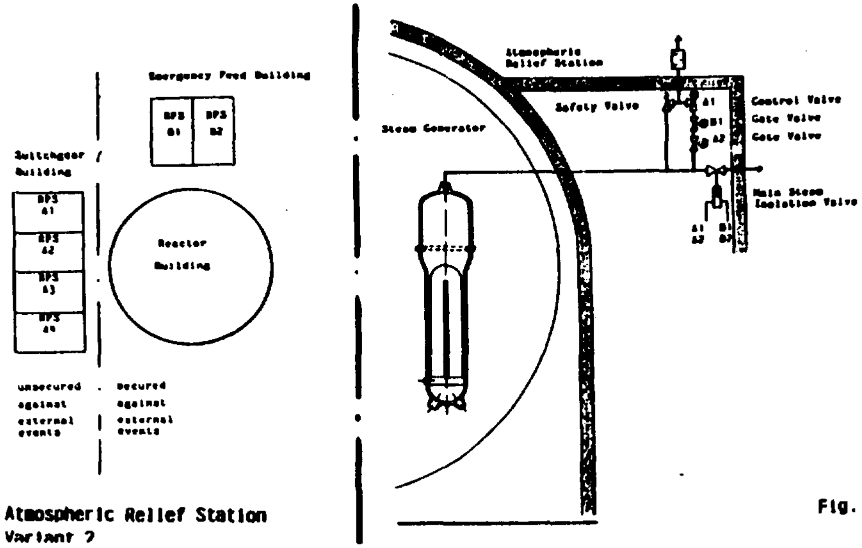


Atmospheric Relief Station Variant 2

Fig. 7

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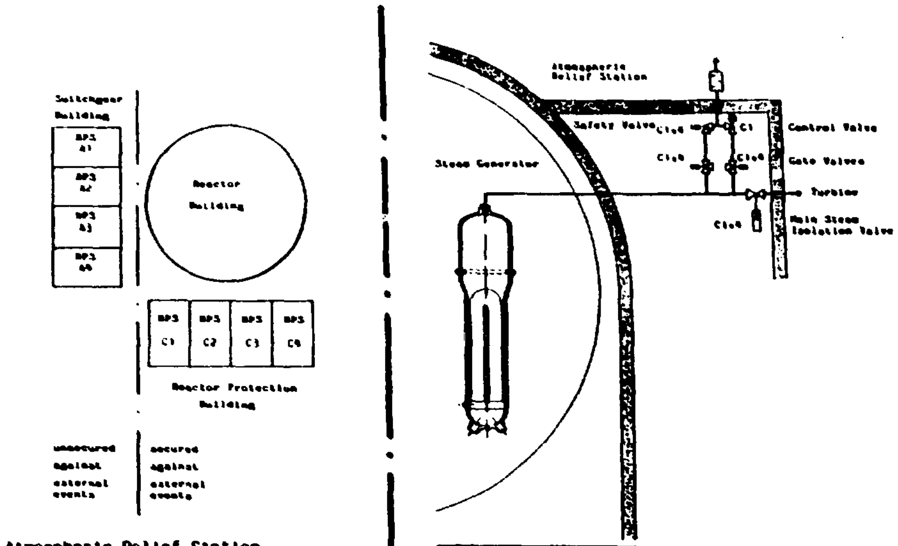
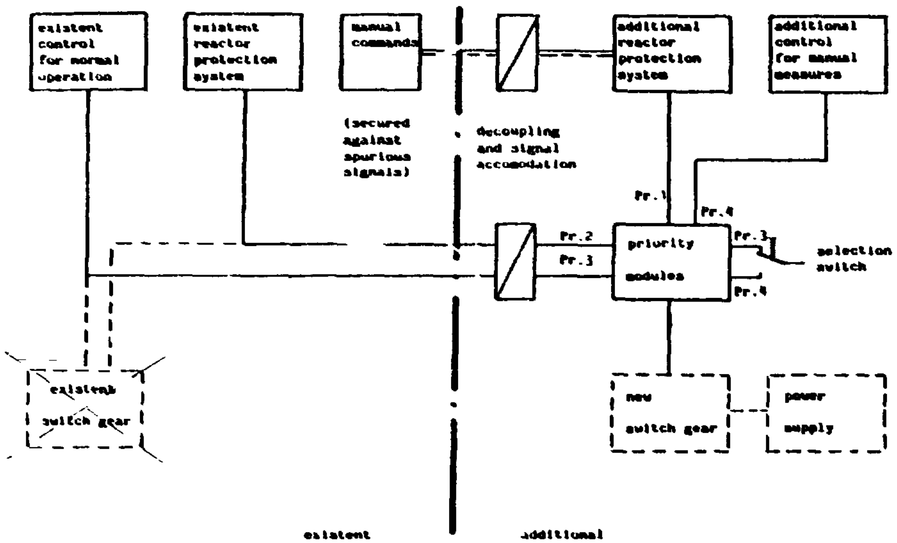



Atmospheric Relief Station
Variant 3

Fig. 8

**Kraftwerk Union**




Organization of additional safety related I + C

Fig. 9



# AUTOMATIC DETECTION AND ANALYSIS OF NUCLEAR PLANT MALFUNCTIONS

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## Abstract

In this paper a system is proposed, which performs dinamically the detection and analysis of malfunctions in a nuclear plant. The proposed method was developed and implemented on a Reactor Simulator, instead of on a real one, thus allowing a wide range of tests.

For all variables under control, a simulation module was identified and implemented on the reactor on-line computer. In the malfunction identification phase all module run separately, processing plant input variables and producing their output variable in Real-Time; continuous comparison of the computed variables with plant variables allows malfunction's detection. At this moment the second phase can occur: when a malfunction is detected, all modules are connected, except the module simulating the wrong variable, and a fast simulation is carried on, to analyse the consequences.

## Introduction

The proposed techniques try to meet the growing demand of safety, especially after TMI accident. Generally in a traditionally built Control-Room, an abnormal condition or a malfunction is signaled by its consequences. By means of tresholds some important variables are supervised. When they are crossed, an automatic safety intervention may occur, or more frequently the operator is asked to take decisions. Often, important alarms may occur depending on trivial reasons and viceversa. Human factors techniques, synoptical and computer aided data presentation can aid operator in taking decisions. But in any case, what it is usually shown are the consequences and not the causes of "malfunctioning" conditions. For example the rise of temperature in the Fuel Core can be generated from loss of coolant, supply fault, pumps seizing etc. Operator must locate the right reason, evaluate consequences and take decisions on the base of its own experience and judgement.