Design implementation of stress-test measures on Czech and Slovak NPPs

Jan Anděl, ÚJV Řež, a. s. ENERGOPROJEKT PRAHA division

Introduction

In the aftermath of Fukushima event, the European Nuclear Safety Regulators Group (ENSREG) asked for an evaluation of the plant robustness in case of extreme external events, loss of power supply or ultimate heat sink and also for ability to mitigate consequences of severe accidents.

This task was resolved in the "Stress tests" frame. The results were, besides other, requirements for additional safety measures to improve NPP robustness. These inputs were transformed into design concepts and later into documents of feasible design. ÚJV Řež, a. s. ENERGOPROJEKT PRAHA division took significant part in these activities together with NPP operators in Czech Republic and Slovak Republic and other subjects.

This paper deals with conceptual design considerations and compares features of various possible technical solutions that further resulted in proposal of design solution. The paper describes these issues for NPP Dukovany and Temelin in Czech republic and for NPP Mochovce, units 3 and 4, in Slovak Republic.

Main tasks resulting from "Stress tests".

Stress test evaluation procedures provided requirements for safety measures. Some of them are site specific, some of them are general. The most general requirement is improvement of Defence in Depth (DID) needed for prevention and mitigation of Severe accidents (SA). Improvement should be composed from following items to be considered.

- New more demanding combinations of external events
- All Units on site can be affected
- Reactor and spent fuel pool can be affected simultaneously
- Various modes of the Unit considered (power operation, refueling…)

Design procedures and available technology

Stress test caused new situation. Effective measures were strongly and quickly required; however standard and technical basis was missing. Lots if principal and extremely simplified proposals and ideas were created without complex evaluation of their feasibility. No reference design solution was available, because also the type of disaster from Fukushima definitely is not directly applicable for central Europe.

After certain initial time delay caused by above mentioned reasons the development of safety measures NPPs in Czech Republic (NPP Dukovany, 4xVVER440, NPP Temelin 2xVVER1000) was governed by "action plans". Development of technical basis and design concept in these conditions is difficult. There was almost no time to prepare normal technical studies needed for use some strongly diverse technology. Same is valid for feasibility studies needed to develop optimum arrangement if systems and thei integration to existing design. The design concepts were therefore prepared based on existing design experience using conventional sorts of equipment and proven design principles (as e.g. functional and physical separation). This design concept was cut to several groups of safety measures that are now directly implemented to detailed design a realization stage.

NPP Mochovce in Slovak Republic, Unit 3 and 4 (MO34, VVER440) is still under construction and work on Basic design still continues. This situation enabled to include all main safety measures into one comprehensive Basic design amendment (BDA) and coordinate them mutually and also with original design solution. Detailed design of safety measures will be worked out on the base of this

BDA. Technology and design principles used in safety measures of MO34 are also very conventional. Reasons are same as in Czech Republic.

Defence in depth improvements

Because the specific event or combination of effects cannot be determined, it was decided to improve essential safety principles. Safety of Czech and Slovak NPP is based on standard principles :

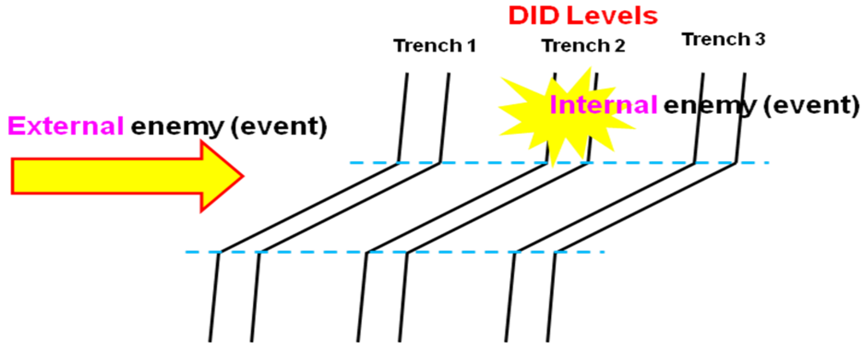
1. Defence in depth (DID) structured in several levels protecting multiple physical barriers against radiation releases.

2. The set of safety functions. Most of these functions is provided by active systems that need some source of power. Systems are arranged in compliance with DID principle in particular levels.

DID is the old and well proven military principle. It can be explained by following sketch showing system of 3 trenches. Trenches shall be mutually independent (these are various DID level) and also sections of same trench shall be mutually independent (principle of safety divisions or trains on NPPs). Robustness of DID depends on:

- Features given given in design (shape, separation, redundancy,…, weapons)
- Quality that includes also inspections and testing
- Trained staff
- Protections (self destruction, that limits propagation of enemy attack).

Such robust DID system protects against attack of external enemy and also enemy hitting inside the system. The system shall enable coordinated and controlled from For NPP the external enemy could be extreme external event (wind, temperature, loss of offsite power…). Internal enemy is for instance a fire or a fault of equipment.



The design of above mentioned NPPs use the systems of DID levels according to IAEA standards. All DID system was analyzed during stress tests and subsequent design activities. Specific improvements were designed in DID1, DID2 and DID3 levels. But most of safety measures were focused to LEVEL 4 that deals with prevention and mitigation of severe accidents (Design extension conditions, DEC). Measures and procedures for prevention are considered same important as mitigative ones.

The table below shows the scheme of typical DID4 sublevels (e.g. scenarios). Station blackout (SBO) of ALL units was evaluated as the most demanding DEC that shall be managed to prevent development to severe accident on more units.

DID 4	**Prevention and mitigation of DEC**	**Period of origin**
DID 4.1	Coping with SBO – External AAC Prevention	Before FUKUSHIMA
DID 4.2	Coping with SBO – Internal AAC Prevention	Before FUKUSHIMA
DID 4.3 NEW	**Coping with SBO – Internal AAC Prevention**	**After FUKUSHIMA Design modification needed**
DID 4.4	Mitigation of SA consequences	Before FUKUSHIMA (only MO34)
DID 4.5 NEW	**Mitigation of SA consequences**	**After FUKUSHIMA Design modification needed** (Only MO34)

The table shows that certain DEC were considered in the NPP design also before Stress tests.

Current measures in Czech NPPs accent robust prevention of SA. A way of the most effective mitigative measure of SA is still in development process, this is valid mainly for NPP Temelin.

The design of NPP MO34 contained preventive and mitigative measures of SA for before Fukushima scenarios. Currents design modification includes measures in compliance with Stress tests outcomes (earthquake, ALL units affected).

The table below compares difficulty of SBO definition (simplified) for before and after Fukushima situation.

SBO definition before Fukushima	**SBO definition after Fukushima**
LOOP - All units (weather, power system failures,…)	same
Single unit – loss of all EDG (CCF)	ALL unit – loss of all EDG (CCF, insufficient withstand)
Other units – safety secured by at least one SS division (mutual help)	Other units – also in SBO, mutual help impossible
Not considered • Seismicity, fires, floodings • DBA • Failures of equipment	Not considered • DBA Considered • Seismicity, fires, floodings • Failures of equipment possible
Quick offsite help assumed (incl. power supply)	Offsite help after 1 day (light) 3 days (heavy) or even later (external power supply

Consideration related to some design questions

Principle question 1: Mobile or stable equipment should be used?

Positive and negative features and capabilities were judged and compared during design concept preparation. General conclusion is:

Preferred measures against DEC (basic level) should be based on **stable equipment** (well protected, diverse as much as reasonably achivable, quickly available, more easily testable and thus more user friendly).

- Fast start and function in any situation.
- Minimum demand on operating staff (standard activation from MCR or local control panels)
- High power (able to secure wider variety of safety functions)
- Better technical compatibility with „DBC“ systems

Mobile equipment should form the **backup level** (very diverse, but available after significant time delay, not very user friendly)

- Possible total resistance against the event (by transport – equipment is not present on site affected by the disaster)
- Transport, connection and start will cause a time delay
- High requirements on skill and capacity of operating staff
- Lower power and performance, lower compatibility with „DBC“ systems.

Table below shows comparison of features for AAC power source in mobile or stable version.

Feature	Mobile	Stable
Protection against event - On site (close) - On site (distant) - Off site (distant)	**By transport** Bunker Bunker Sufficiently robust shelter	**By distance** Bunker Bunker Not feasible due to technical or price reasons
Transport	Expected **problems** (mainly with heavy, more powerful equipment)	N/A – stable equipment
Connection	Where? How? Who? (difficult in real disaster situation)	Permanently connected, prepared
Start of function	After connection, **with large time delay**	**Fast** (minutes), could be automatic
Voltage and Power	**LV (400V)** close to LV consumers **Low power -** (sensitive on behavior of consumers and failures in distribution)	**MV (6kV)** – protection by distance possible **High power –** non sensitive, tolerates mistakes, transients
Compatibility with EEPS (design basis systems)	**Incompatible** (selectivity corrupted)	**Compatible** (selectivity is kept)
Testing – functionality in real disaster situation	Realistic test of transport, connection … **is difficult** (simulation wouldl be demanding for operation staff – **military skill needed**)	Regular **periodical tests possible** (similar as for design EEPS)

These considerations lead to following principal designs:

– Mobile equipment (e.g. mobile dieselgenerator) with relatively big power is installed in robust shelter (bunker) close to load and hardwired to power distribution. This mobile DG is in fact the stable equipment, keeping most of its advantages, however with possibility to be transported to another place in case of necessity. This design is used on MO34. Mobile DGs supplemented by fire trucks (supply of coolant) form diverse and quickly available solution and almost full scope backup to stable systems.

– Mobile equipment (DG) is light, stored in distant shelter. It will be used in case of very critical situation when stable systems failed. This design calculates with time delay needed for transport, connection and putting in operation. Light mobile equipment is able to provide only very limited scope of safety functions, always in combination with mechanically driven systems as fire truck. This design seems to be appropriate for robust design of stable means, it is in development for NPPs Temelin and Dukovany.

Principle question 2: Location of stable equipment

Some of very early ideas of safety measures presumed location of mechanically or electrically driven additional pumps in direct surrounding of main power block or reactor building. Relatively simple equipment, probably in container was assumed.

Performed risk analyses showed that such a solution cannot be used in situation that potential disaster is caused by extreme external effects. It is difficult to trust that equipment in some container would survive in conditions that caused malfunction of bunkered emergency dieselgenerator and pumping stations of DBC systems. This objection is pretty good obvious from layout scheme of electrical emergency power systems (EEPS) of NPP Temelin. EEPS 1,2,3 ale located on different sides of reactor building, same is valid for their emergency DGs.

This risk assessment leads following design principles for additional safety systems and their buildings.

– New the technological systems and its shelter building shall be sized according to more strict requirements than DBC systems to be backed.

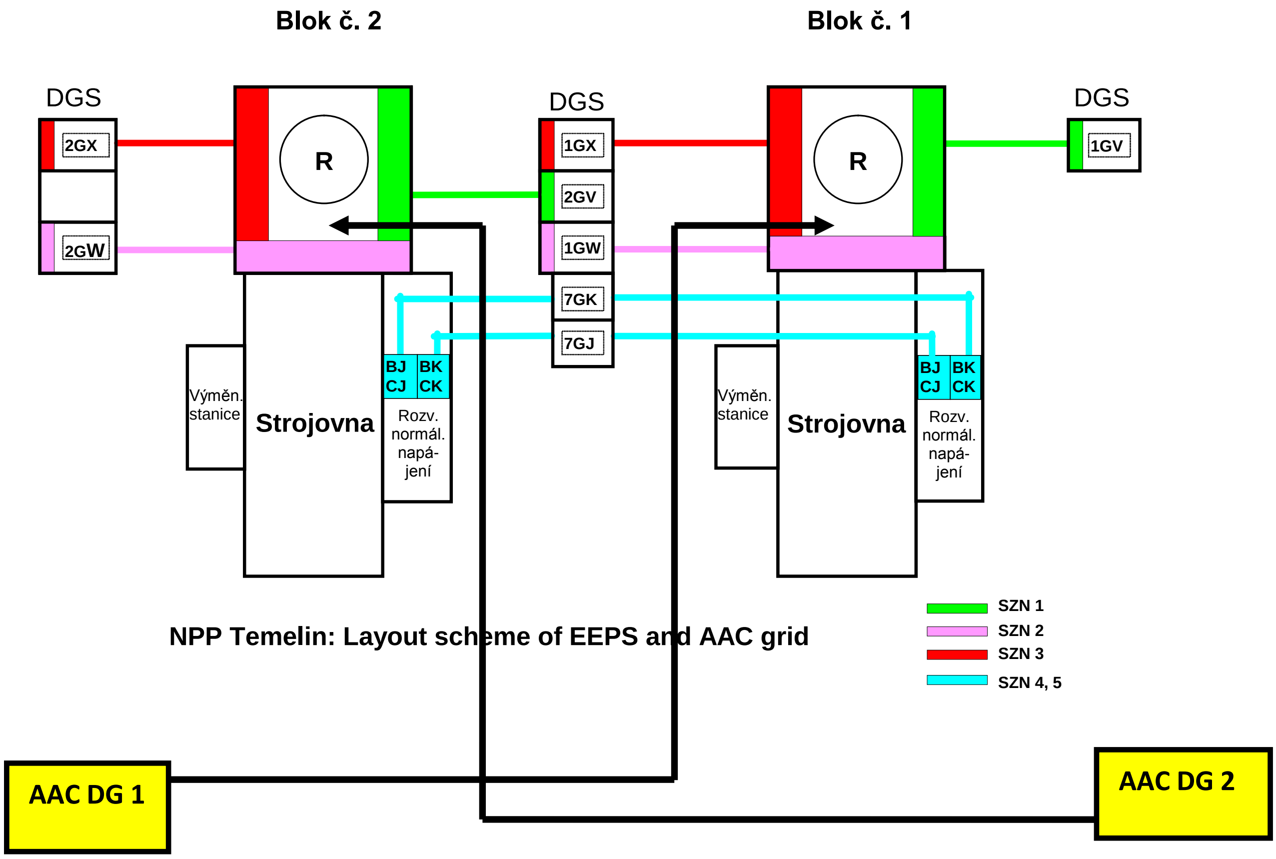
– New technological systems and its shelter building shall be located in significant distance from DBC systems to be backed.

As an example of use of these design rules all NPP Temelin systems performing “stress tests” safety functions are located:

– In robust seismically resistant reactor building

– In new AAC DG stations distant several hundred meters from DBC diesel stations

– In seismic channels of essential service water.



Conclusions – common features of stress tests safety measures

NPPs will have following significantly improved safety features after design and implementation of stress test measures:

1. Increased robustness of DID (further independent sublevels in relation to every detected "cliff edge" effects).
2. Wider scope of NPP accident operating modes and accident scenarios addressed. DEC considered even at all Units on site.
3. Previous safety measures and procedures sufficient for coping with less difficult events are usually preserved
4. New safety measures must not decrease performance of design basis safety functions
5. Minimization of the need of human intervention during the first phases of accident scenarios declared in some cases is not realistic. Particularly due to effort for more economical design significant scope of direct human actions is needed.
6. Higher preference is given to "passive" or manually operated systems (i.e. storages of coolant, longer battery autonomy time, battery supplied or manual actuations, etc.)
7. Emphasis was given to keep the plant in "safe" conditions within 72 hours from the accident onset, also with the support of in-site contributions. Later is assumed effective external help and repair of some portion of DBC systems.

8. The combination of mobile and stable means is used. Hardened stable means are more essential, mobile more backup. Use depends on the event and scenario of solution. Flexibility is accented.
9. Design solution enables fulfillment of safety functions even upon failures of equipment. The principle of functional groups (FSK) is used. Preventive measures (coping with SBO) have higher ability to cope with failures. For SA mitigation measures is this ability at least partial.

LITERATURE:

Conceptual design of Stress test safety measures, NPP Dukovany, NPP Temelin, ÚJV Řež, a. s. ENERGOPROJEKT PRAHA division, 07/2012

Basic design amendment No. 0048 for NPP Mochovce, Units 3 and 4, ÚJV Řež, a. s. ENERGOPROJEKT PRAHA division, 09/2013