Radiological Events Feedback as a Tool of Dose Reduction at the Dukovany Nuclear Power Plant: Results

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Abstract

The State Office for Nuclear Safety (hereinafter referred to as the "SONS") executes the duties of the Czech regulatory body for all the Czech nuclear facilities. The Dukovany Nuclear Power Plant (hereinafter referred to as the "NPP") is supervised from the SONS Regional Center Brno. During the period, VVER reactors from the Czech Republic showed low values of the average annual dose per reactor, which approaches value 100 mSv all over the world for the first time. In addition, the total number of events with a radiological cause is kept at a very low level during NPP operation. The achieved results are assured by both internal and external surveillance, i. e., by radiation protection services of the licensee and by the SONS as a national regulatory body. The paper presents the ways used as a feedback tool. It shows an analysis of all main events at the Dukovany NPP, including a survey of general achievements in the field of radiation protection.

There are three main causes of radiological events:

- Human error,
- Facility failure,
- Project deficiency.

The number of all existing radiological events is small and their consequences are negligible. In spite of this fact, each event is thoroughly investigated as a possible source of a more significant incident. Most events have an origin in a technological part breakdown, and radiological consequences resulting from technological failure occur due to radioactive medium release.

Since 2002 each safety performance indicator describing the real safety situation at reactor units of the Dukovany NPP has had a positive trend.

The trends of safety performance indicators and analyses of the events shown for the Dukovany NPP are summarized in this paper. This presentation also brings forward a discussion about ALARA implementation by the licensee and resulting co-operative actions taken by the SONS and supporting internal licensee's procedures.

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1. Introduction

Two nuclear power plants, Dukovany NPP and Temelin NPP, are operated in the Czech Republic. This paper deals with the oldest Czech NPP, Dukovany NPP. Original Russian project combining a Russian design and a Czech hardware including instrumentation and control systems (hereinafter referred to as the "I&C") proved competent by more than 20 years performance. Now, the Dukovany NPP ranks among the first fifth best operated NPPs in the world. There are spheres in which the Dukovany NPP has achieved the top on the international scale in the Dukovany NPP operation and these involve radiation protection, fuel performance and the unit capability. These excellent safety performance results have been achieved under complicated conditions of the original Russian VVER 440 project (gross output of the unit 440 MW) reconstructed into quite a new plant with the up-to-date I&C, and with a higher fuel load giving a new gross output of 500 MW for each unit. After the mentioned reconstruction to be completed in 2012, the Dukovany NPP will have the installed output 2000 MW instead the former 1760 MW designed in the original project.

2. Radiation protection

The collective radiation exposure indicator monitors the effectiveness of personnel radiation exposure controls including the influence of both licensee and regulator activities. Fig. 1 shows the course of that indicator for all four units at Dukovany NPP in 1997 – 2008. An explanation for the decreasing trend of doses at the Dukovany NPP is presented in [1].

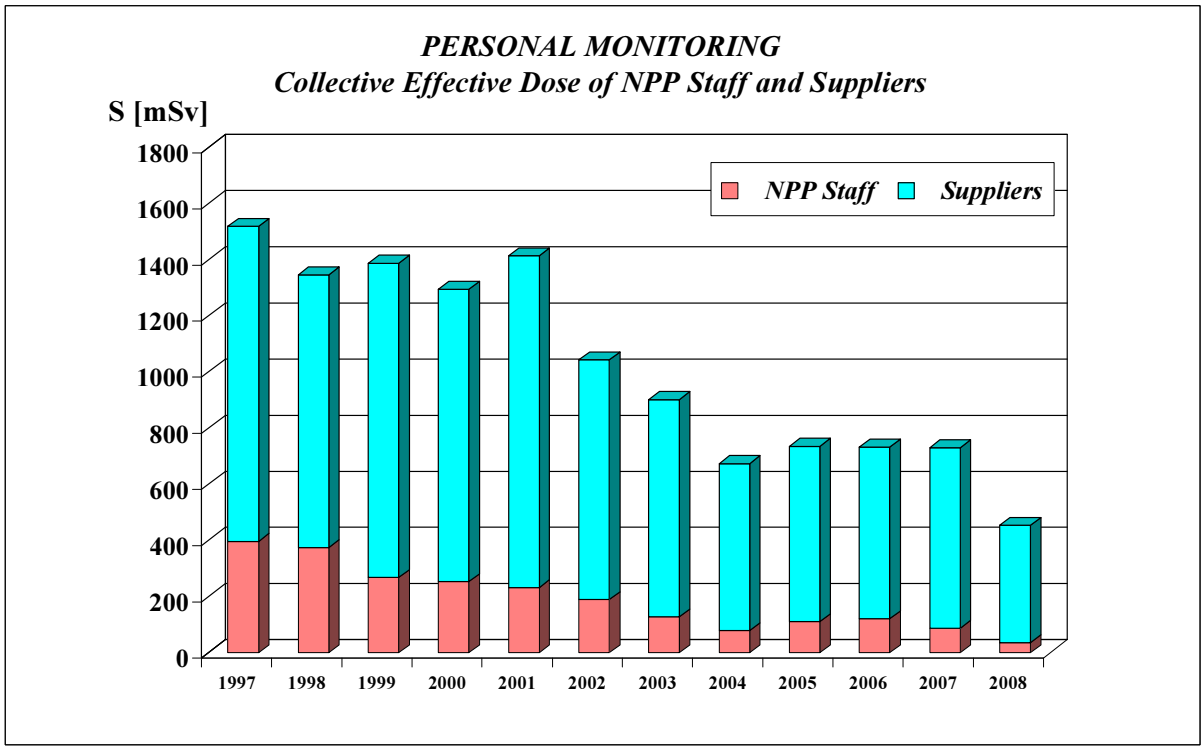

Fig. 1 – Collective effective dose S at Dukovany NPP for both groups of exposed workers, NPP staff and NPP suppliers, in 1997 – 2008, mSv in the current year.

The diagram in Fig. 2 presents a different view of the dose as an indicator of collective radiation exposures per unit. This presentation of the indicator allows to show the mutual benchmarking among NPPs more appropriately.

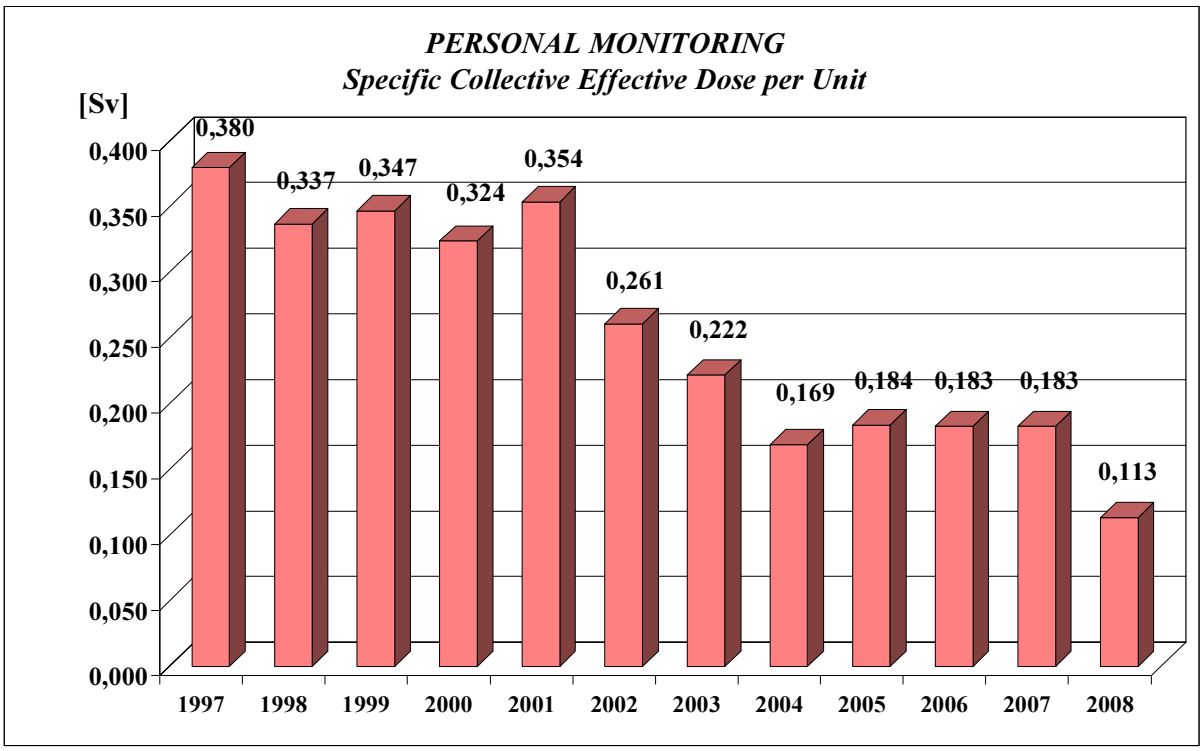

Fig. 2 – Specific collective effective dose S/unit at Dukovany NPP as a sum of both groups of exposed workers, NPP staff and NPP suppliers as S per unit, in 1997 – 2008, Sv per unit in the current year.

As seen in Fig. 2, the dose is extremely low in 2008 and it is even lower than doses proposed and projected as a standard for the newest designed reactors when the level for a collective dose objective is set to 0.35 man.Sv/year per EPR unit of EDF [2]. According to Ref. [3]: *"The collective exposure target, which shall be fulfilled by the EPR in normal operation, is specified as follows:*

- *A collective dose of 0.5 man-Sv per year has to be kept for EUR. Routine maintenance and a standard in-service inspection program have to be taken into account. This is an average over the years of normal operation.*

By target we imply, of course, that the collective dose is constrained not to reach this target. The target is meant in the sense of expressing an upper ceiling below which design dose estimation results have to remain.

The target was based on an analysis of the actual data from French and German PWRs at the time of specification in 1992. The best results at that time were 0.2 man-Sv per year per unit for the newest Konvoi-plants (this value should be compared to the initial design target of 1 man-Sv per year for these plants) ".

Specific doses (Sv per year per unit) lower than 0.2 are achieved at the Dukovany NPP after 2003. The low dose in the year 2008 is related basically to fewer exposed workers entering radiation control area (hereinafter referred to as the "RCA"). The decrease is minus 60 exposed workers in year 2008 in confrontation with year 2007. This decreasing trend also brought about a reduction in the total time needed for shutdown of the units: 144 days in 2008 and 176 days in 2007. Although both the number of workers and the

time spent for refueling and maintenance during unit shutdown were reduced, the individual doses remained at the same low level. Fig. 3 shows the course of maximum individual occupational exposures and Fig. 4 illustrates the keeping of low individual exposures despite of shutdown time reduction.

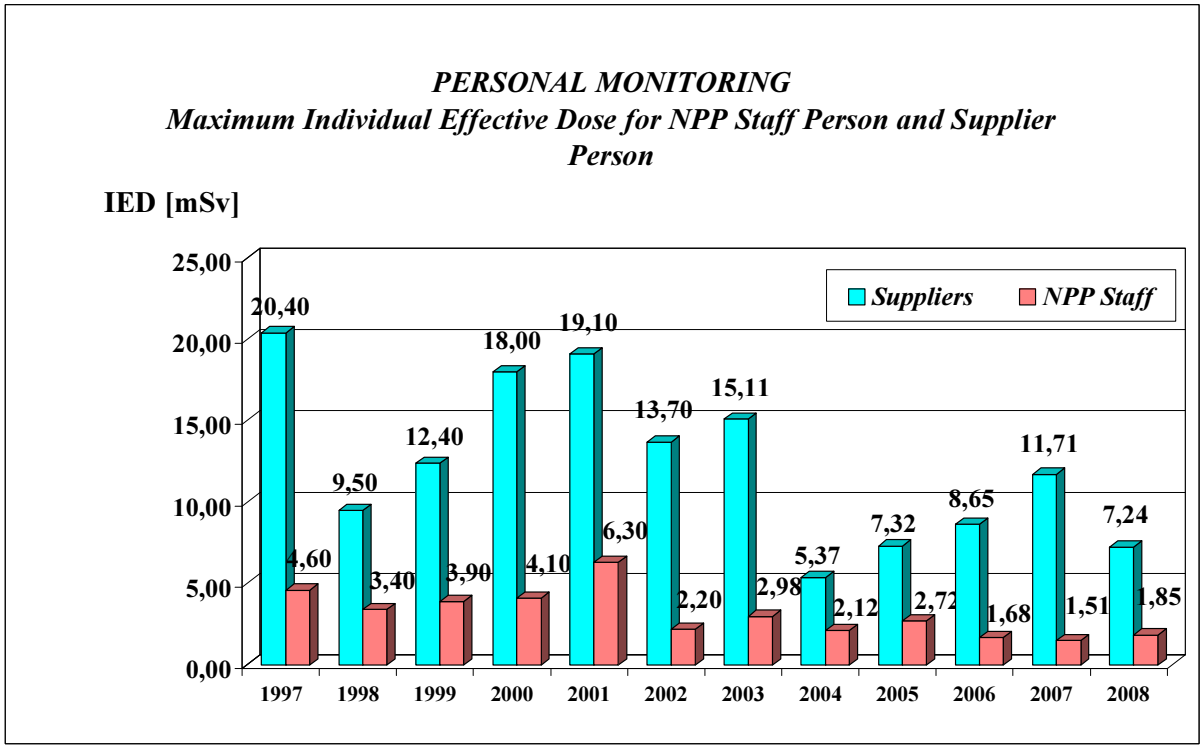

Fig. 3 – Maximum individual occupational exposures at the Dukovany NPP in 1997 – 2008

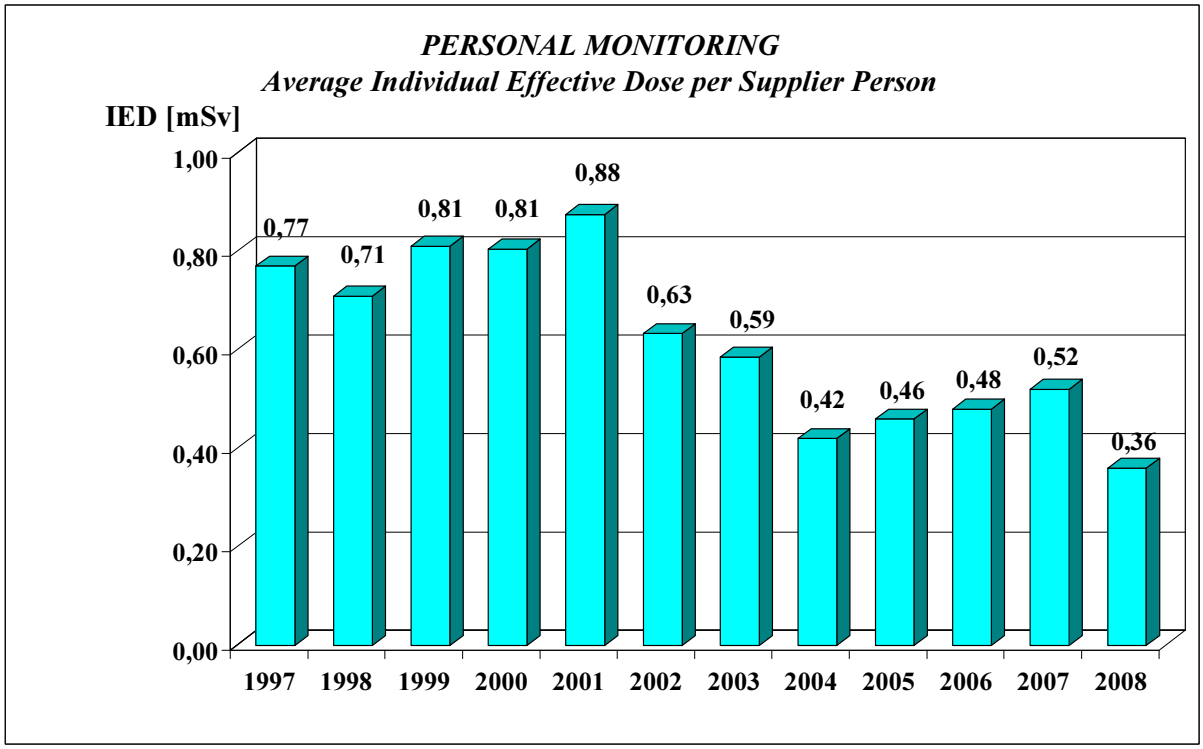

Fig. 4 – Average individual occupational exposures at the Dukovany NPP in 1997 – 2008

As seen in Fig. 4, the individual doses had a constant course in the last five years.

3. Events

Fig. 5 illustrates the number of radiation events or events with certain relation or link to radiation protection.

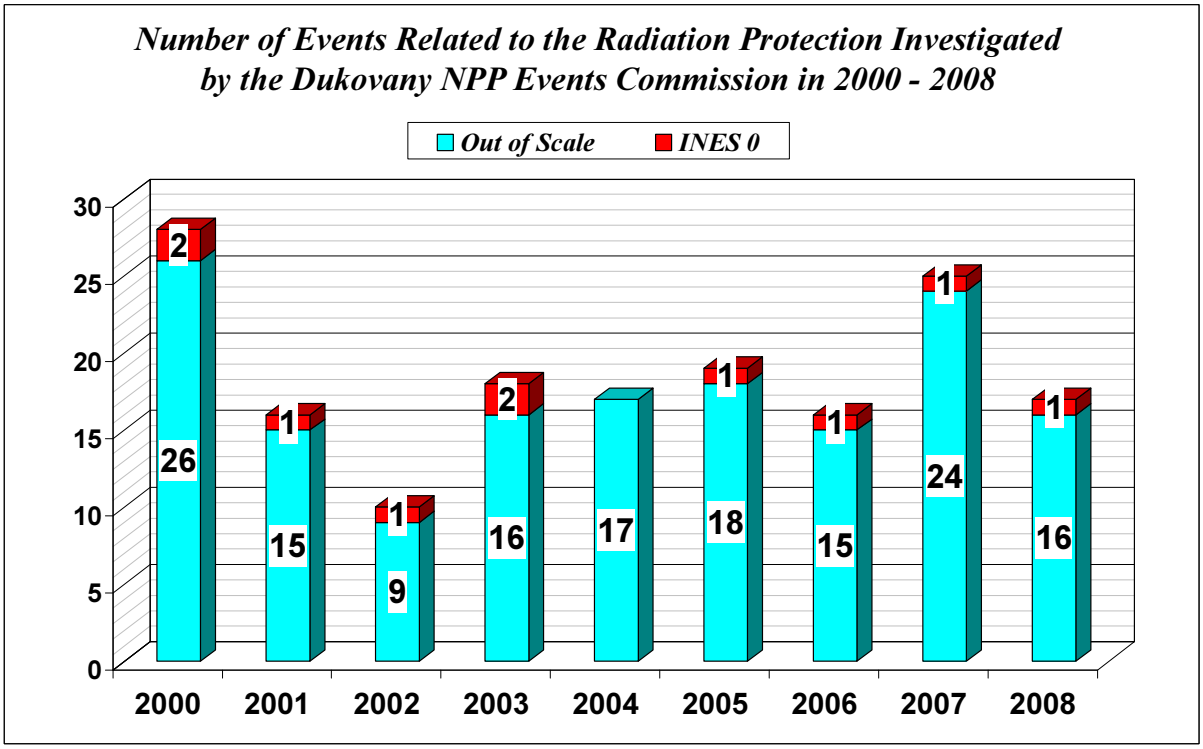

Fig. 5 – Number of events related to radiation protection and investigated by the Dukovany NPP Events Commission in 2000 – 2008

From Fig. 5 it is evident that the number of investigated events is small and the majority of them are unrelated to radiation protection assurance and they have no relation to radiation protection. There are criteria for determination of events as non-significant events or events without relation to radiation protection from the radiation protection point of view and events with some relation to radiation protection. Nevertheless, it is differentiated between events with no safety significance, below scale (INES rating 0) and inconsequential, non-significant events (Out of INES scale; in the Czech Republic also marked as INES * or INES x because INES = 0 is an event below scale but INES = * is event out of scale).

Non-significant events, i.e. events out of scale from the radiation protection point of view must simultaneously fulfill all the conditions given bellow:

3.1 No human radioactive contamination,
3.2 No unnecessary exposure,
3.3 No production of radioactive wastes,
3.4 No operating limit is exceeded (operating limits are below the reference levels approved by the SONS; operating limits serve the operator as the first capturing barrier for a potentially developing event, this barrier allows to detect any radiological event deep below the approved limits)
3.5 Compliance with the conditions stated in Ref. [4].

The above mentioned conditions are processed into the internal Dukovany NPP safety operating procedures with factual values and limits. Although the INES rating was not originally intended as an event evaluating tool, it has often been used in that way in the

Czech NPPs. Besides the INES rating methods, internal operating procedures developed for each Czech NPP are basically used. These operating procedures have priority over the IAEA INES documents, because these procedures are derived from the national Czech legislation. However, the international standards are taken into account and serve as an additional assessing tool. What kinds of events undergo this evaluation? And what is the evaluating process?

Every event undergoes the evaluating process. This process is described in the relevant documentation related to quality assurance. The quality assurance documentation is the top documentation in the structure of operating procedures. According to the mentioned documentation every event is processed by the event solution system (see Fig. 6).

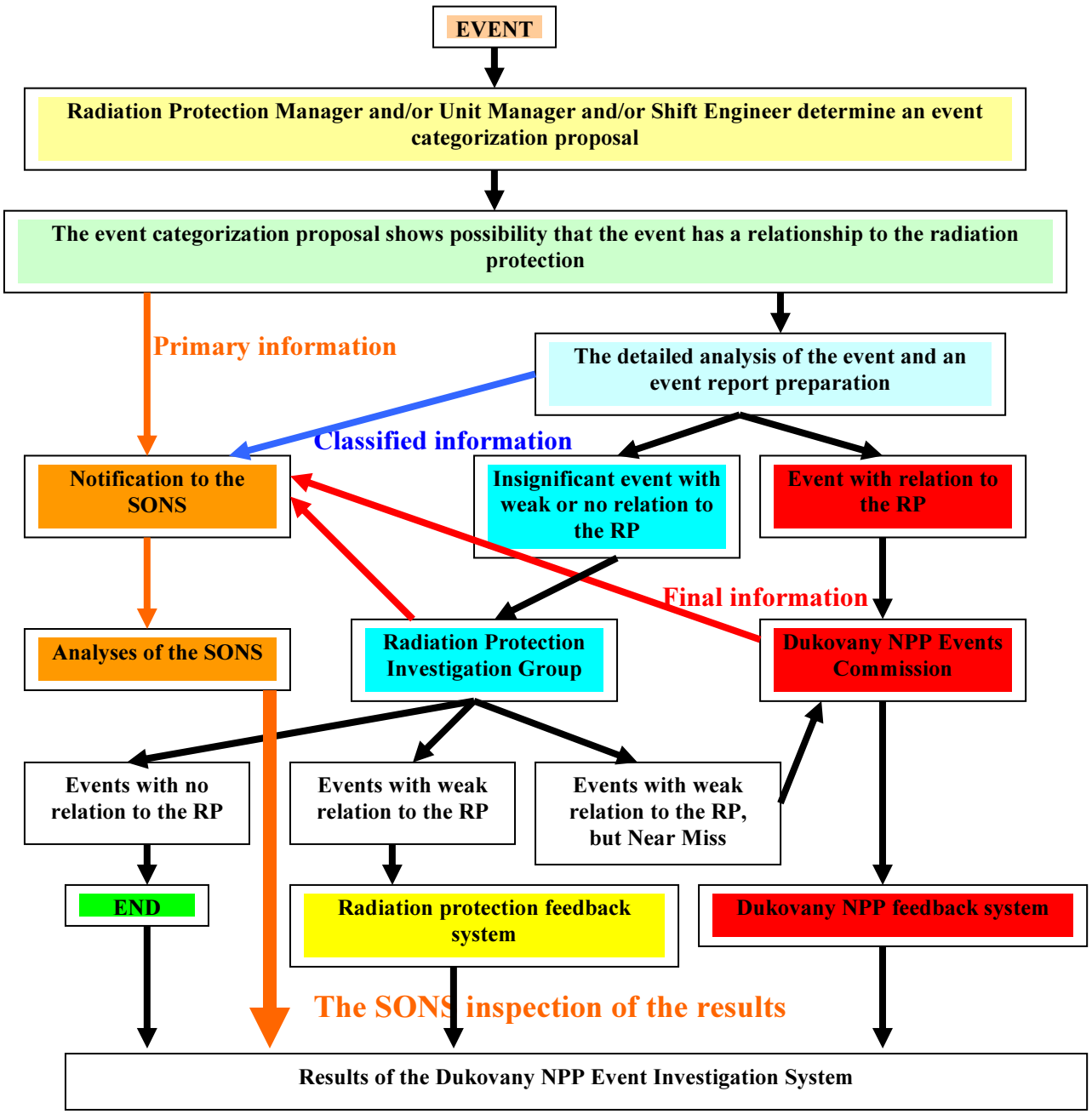

Fig. 6 – Framework of the radiological event solution system at the Dukovany NPP and its relations to the SONS

As every event occurring at the NPP undergoes the process described above, every really dangerous event is captured with a very high efficiency.
As an example this paper brings results of the Event Feedback System in the radiation protection field at the Dukovany NPP in year 2008. These results are given in the Table 1.

Table 1 – Events with some link to the radiation protection investigated at Dukovany NPP in year 2008 (Dukovany NPP has four units each 440 MW)

No.	Date	Unit	Event Description	Cause	Investigated/ INES
1	**February 17**	**3**	Escaped water from the bubble condenser (facility is a part of the Emergency Core Cooling System - ECCS). Affected area cca 25 m^2, released volume cca 100 L, volume activity 1.9 * 10^4 Bq/L. Conditions 3.1 – 3.5 were fulfilled.	**HF**	Radiation Protection Investigation Group[3]/ INES = *
2	**February 24**	**4**	Leakage from a pipeline of the normal feeding pump. Inconsiderable leak of the feeding water to the primary circuit. Conditions 3.1 – 3.5 were fulfilled.	**TF**	RPIG/ INES = *
3	**February 29**	**4**	Failure of the Low Pressure ECCS Pump with escaped water. Affected area cca 30 m^2, released volume cca 140 L, volume activity 1.0 * 10^4 Bq/L. Conditions 3.1 – 3.5 were fulfilled. Despite stated facts the event was categorized by the Dukovany NPP Events Commission as the category INES = 0.	**TF**	RPIG/ INES = * Dukovany NPP Events Commission[4]/ INES = 0
4	**May 6**	**2**	Fast acting isolation valve plane of separation failure with inconsiderable leak. Conditions 3.1 – 3.5 were fulfilled.	**TF**	EDU EC/ INES = *
5	**May 22**	**2**	Inconsiderable leakage from an I&C device. Conditions 3.1 – 3.5 were fulfilled.	**TF**	RPIG/ INES = *
6	**May 22**	**2**	Inconsiderable leakage from an I&C device. Conditions 3.1 – 3.5 were fulfilled.	**TF**	RPIG/ INES = *
7	**August 14**	**4**	Loss of normal feeding pump operation from failed pressure meter of that pump. Affected area cca 1 m^2, released volume cca 0.5 L, volume activity cca 1.0 * 10^4 Bq/L. Conditions 3.1 – 3.5 were fulfilled.	**TF**	RPIG/ INES = *
8	**September 5**	**4**	Loss of normal feeding pump operation from failed pressure meter of that pump. Repeated failure. Affected area cca 3 m^2, released volume cca 10 L, volume activity 46.5 * 10^4 Bq/L. Conditions 3.1 – 3.5 were fulfilled.	**TF (HF?)**	RPIG/ INES = *
9	**September 15**	**1**	It was realized water release from the I&C device air outlet inside containment. Affected area cca 30 m^2, released volume cca 300 L, volume activity 2.31 * 10^5 Bq/L. Conditions 3.1, 3.2, 3.3, and 3.5 were fulfilled. Condition 3.4 were exceeded, values of the reference levels from monitoring programs were not achieved.	**TF**	RPIG/ INES = *

[3] Hereinafter referred to as the "RPIG".
[4] Hereinafter referred to as the "EDU EC".

No.	Date	Unit	Event Description	Cause	Investigated/ INES
10	**October 7**	**1**	Leakage from an I&C device. Affected area cca 5 m^2, released volume cca 60 L, volume activity 317 Bq/L. Conditions 3.1 – 3.5 were fulfilled.	**TF**	RPIG/ INES = *
11	**October 14**	**9**[5]	Capture of contaminated shoes at the main gate exit of the Dukovany NPP. It was realized that shoes were not used within Dukovany NPP RCA but they were contaminated inside Temelin NPP RCA. Conditions 3.1 – 3.5 were fulfilled for Dukovany NPP, not for Temelin NPP.	**Safety Barrier Break-Through by worker**[6]**, HF**	EDU EC/ INES = * for Dukovany NPP, INES = 0 for Temelin NPP
12	**October 21**	**0**[5]	Contaminated exposed worker from a supplier company. Decontamination was carried out as a special decontamination by a medical assistance because of impossibility of a normal decontamination. Staff of the Dukovany NPP was not directly involved to that event.	**HF**	RPIG/ INES = 0 for supplier, INES = * for Dukovany NPP
13	**October 23**	**1**	Unlooked-for outflow from jet nozzles of emergency shower due to ECCS tests inside containment. Root cause was leak fast acting isolation valve. Affected area cca 50 m^2, released volume cca 2500 L, volume activity cca 10^5 Bq/L. Conditions 3.1, 3.2, 3.3, and 3.5 were fulfilled. Condition 3.4 were exceeded, values of the reference levels from monitoring programs were not achieved.	**TF**	RPIG/ INES = *
14	**October 23**	**1**	Contaminated exposed worker from a supplier company. Decontamination was carried out as a special decontamination by a medical assistance because of impossibility of a normal decontamination. Staff of the Dukovany NPP was not directly involved to that event.	**HF**	RPIG/ INES = 0 for supplier, INES = * for Dukovany NPP
15	**November 10**	**4**	Contaminated exposed worker from a supplier company. Decontamination was carried out as a special decontamination by a medical assistance because of impossibility of a normal decontamination. Staff of the Dukovany NPP was not directly involved to that event.	**HF**	RPIG/ INES = 0 for supplier, INES = * for Dukovany NPP

[5] Numbers 1, 2, 3, 4 indicates the unit number, number 0 means the facility or device belonging to the first double-unit, number 7 is the second double-unit, and number 9 marks device belonging to the whole territory of the Dukovany NPP

[6] Safety barrier break-through was carried out at Temelin NPP, because typical radionuclide mixture analyzed on the shoes surface was typical Temelin's mixture.

No.	Date	Unit	Event Description	Cause	Investigated/ INES
16	**November 21**	**4**	Escaped water from the bubble condenser (facility is a part of the Emergency Core Cooling System - ECCS). Affected area cca 2 m^2, released volume cca 5 L, volume activity 2.87 * 10^4 Bq/L. Conditions 3.1, 3.2, 3.3, and 3.5 were fulfilled. Condition 3.4 were exceeded, values of the reference levels from monitoring programs were not achieved.	**HF**	RPIG/ INES = *
17	**November 21**	**4**	Contaminated exposed worker from a supplier company. Decontamination was carried out as a special decontamination by a medical assistance because of impossibility of a normal decontamination. Staff of the Dukovany NPP was not directly involved to that event.	**HF**	RPIG/ INES = 0 for supplier, INES = * for Dukovany NPP

Explanation: HF, Human Factor; TF, Technological Failure. The only event categorized as INES = 0 is event No. 3.

4. Conclusions

Some results of the Dukovany NPP safety performance in terms of both occupational exposures and radiological events are presented. Both these areas are evidently well controlled. Occupational radiation exposures are kept as low as it is the goal for the next generation of NPPs. The number of radiological events approaches statistical insignificance. The data of both the WANO and the IAEA indicators show that, in the Czech nuclear power plants, and Dukovany NPP in particular, operation is stable and safe and meets the standard of every normal power plant.

5. References

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[4] The IAEA's International Nuclear Events Scale (INES), IAEA, OECD/NEA, Vienna 2001