



International Atomic Energy Agency

P8: Risk Monitoring and Managing Risk Configuration

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Application of Level 1 Probabilistic Safety Assessment

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5 – 9 September, 2022

Risk Monitor

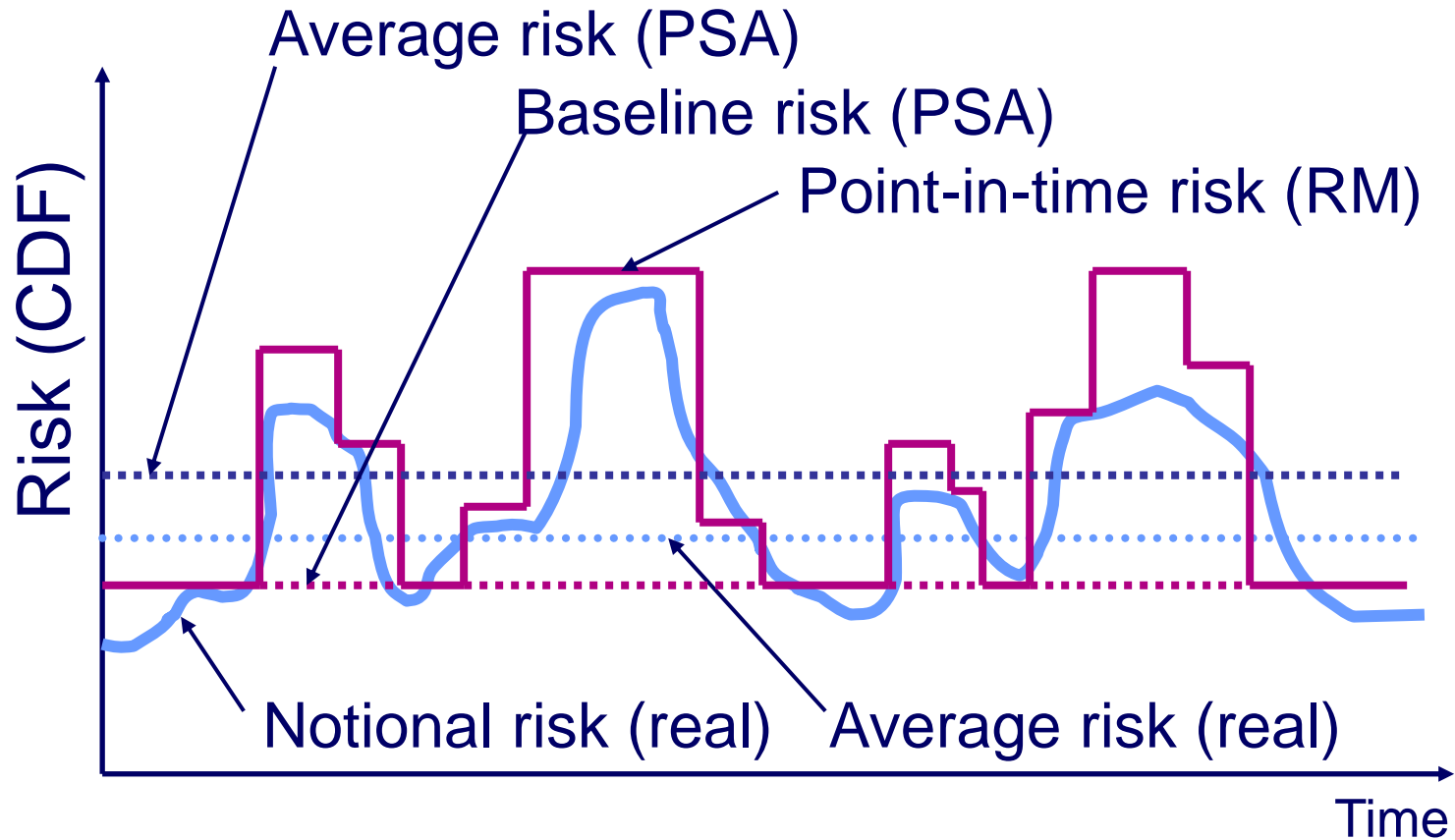
“A plant specific real-time analysis tool used to determine the instantaneous risk based on the actual status of the systems and components. At any given time, the Risk Monitor reflects the current plant configuration in terms of the known status of the various systems and/or components – for example, whether there are any components out of service for maintenance or tests. The Risk Monitor model is based on, and is consistent with, the LPSA. It is updated with the same frequency as the LPSA. The Risk Monitor is used by the plant staff in support of operational decisions”

IAEA definition (IAEA-TECDOC-1101)

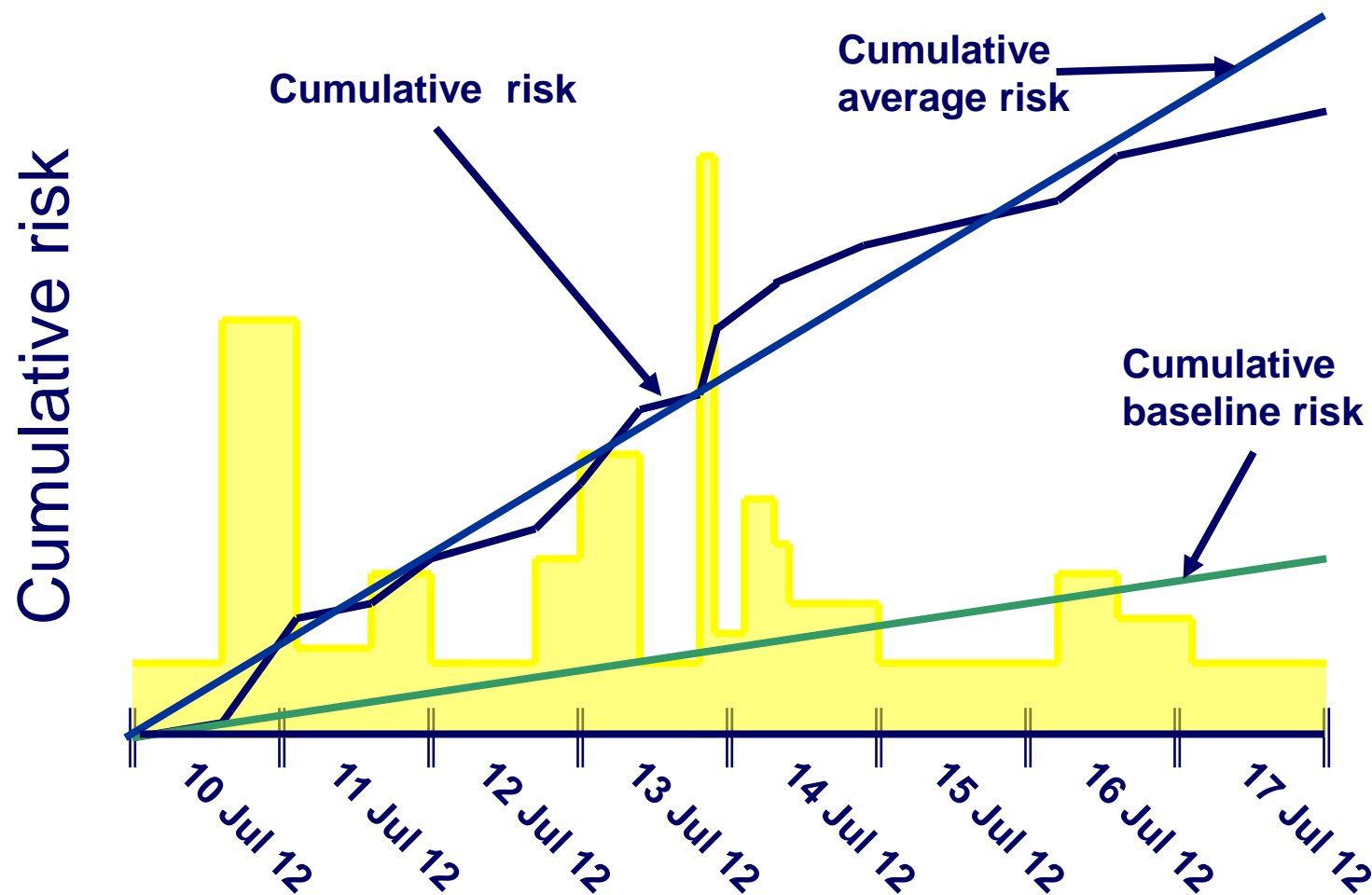
Typical Risk Monitor functions

- **Display plant risk for any configuration**
 - CDF, LERF, loss of shutdown cooling
 - changes in plant risk over a period of time; cumulative risk
- **Display safety system availability**
- **Calculate/ monitor Allowed Configuration Time**
- **Input plant configuration changes/ maintenance schedule**
- **Storage/ retrieval/ display of historical configuration data**
- **Address “**what if?**” questions for changes to plant configuration (**hypothetical mode**)**
- **Carry out maintenance planning**

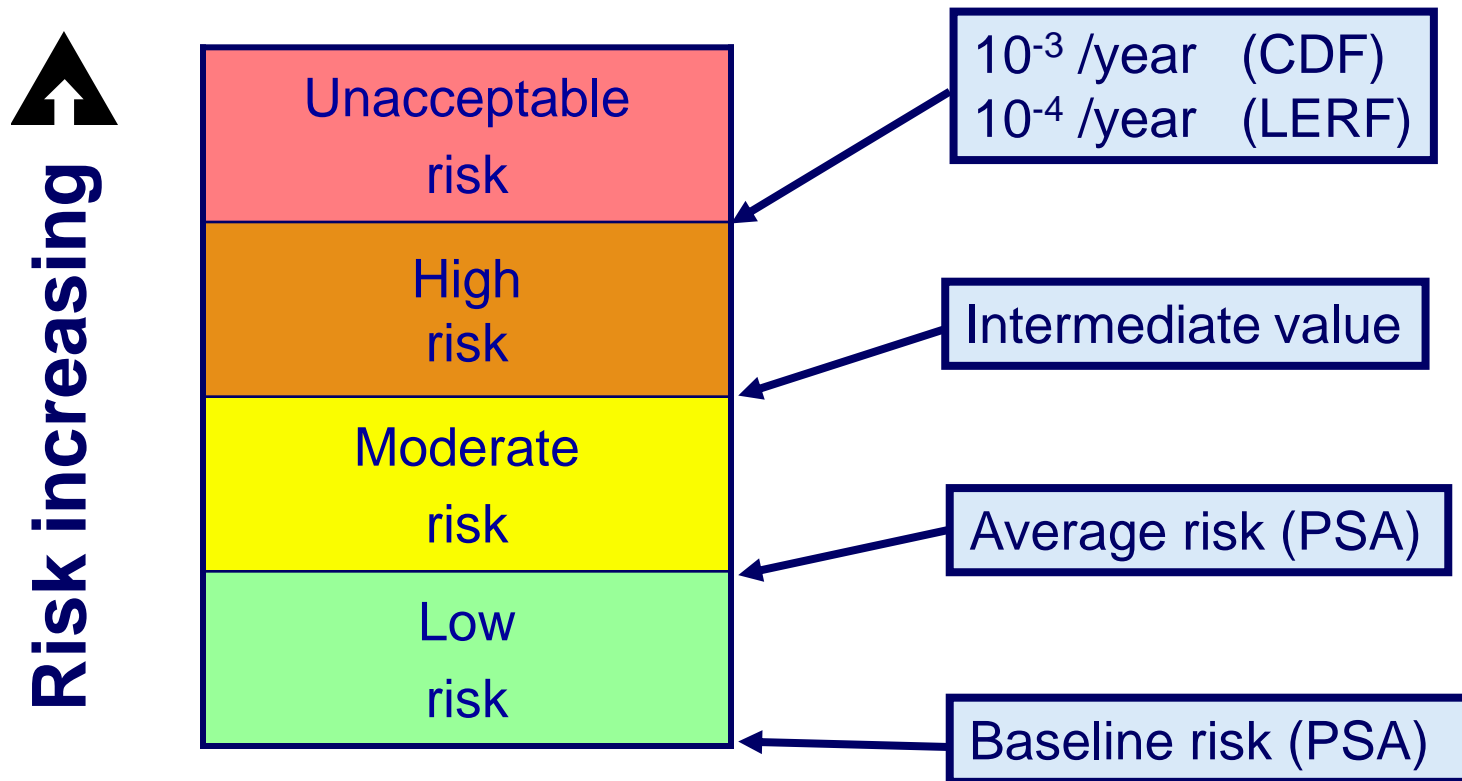
Plant risk



Cumulative Risk



Operational Safety Criteria



Typical usage of riskmonitor software at the NPP

1. Operators in control room

- real-time evaluation of the plant risk during the full power operation and during the low power and shutdown operational modes

2. PSA Team (on-site)

- evaluation of the risk from special unexpected events,
- monthly, quarterly and annual risk reports, etc.
- AOT calculations

3. Maintenance Team – Outage Risk Management

(online maintenance planning and maintenance planning during refuelling outage)

- preliminary evaluations of the planned maintenance schedules to minimize high-risk configurations
- evaluation of the real maintenance schedules

Control of Access

- **General user/ all plant staff**
 - view current/ past risk profiles/ data
 - input hypothetical plant configurations
- **Maintenance planner**
 - as above plus input/ manipulate proposed maintenance schedules
- **Control room operator**
 - as above plus input/ edit actual plant configurations
- **Risk Monitor Administrator (PSA expert)**
 - as above plus import/ edit PSA model and databases

Development of Risk Monitor PSA Model

- **Average PSA is not useable directly for a Risk Monitor application**
- **Typical changes required to PSA**
 - removal of asymmetries
 - model system alignments; running/ standby trains
 - review screening in LPSA
- **Enhancements often made to the PSA**
 - better common cause failure model
 - revised human error probabilities
- **Required to verify that the Risk Monitor results are consistent with PSA**
 - produces equivalent cut-sets
 - results for new features are correct (to cover the CCF model, HEPs, dynamic events, alignments not included in PSA, etc. as appropriate)

Risk Monitor Operation

- **Inputs: plant configuration information**

- components removed from service
- system line-ups
- mode of operation
- environmental factors

- **Outputs: risk information**

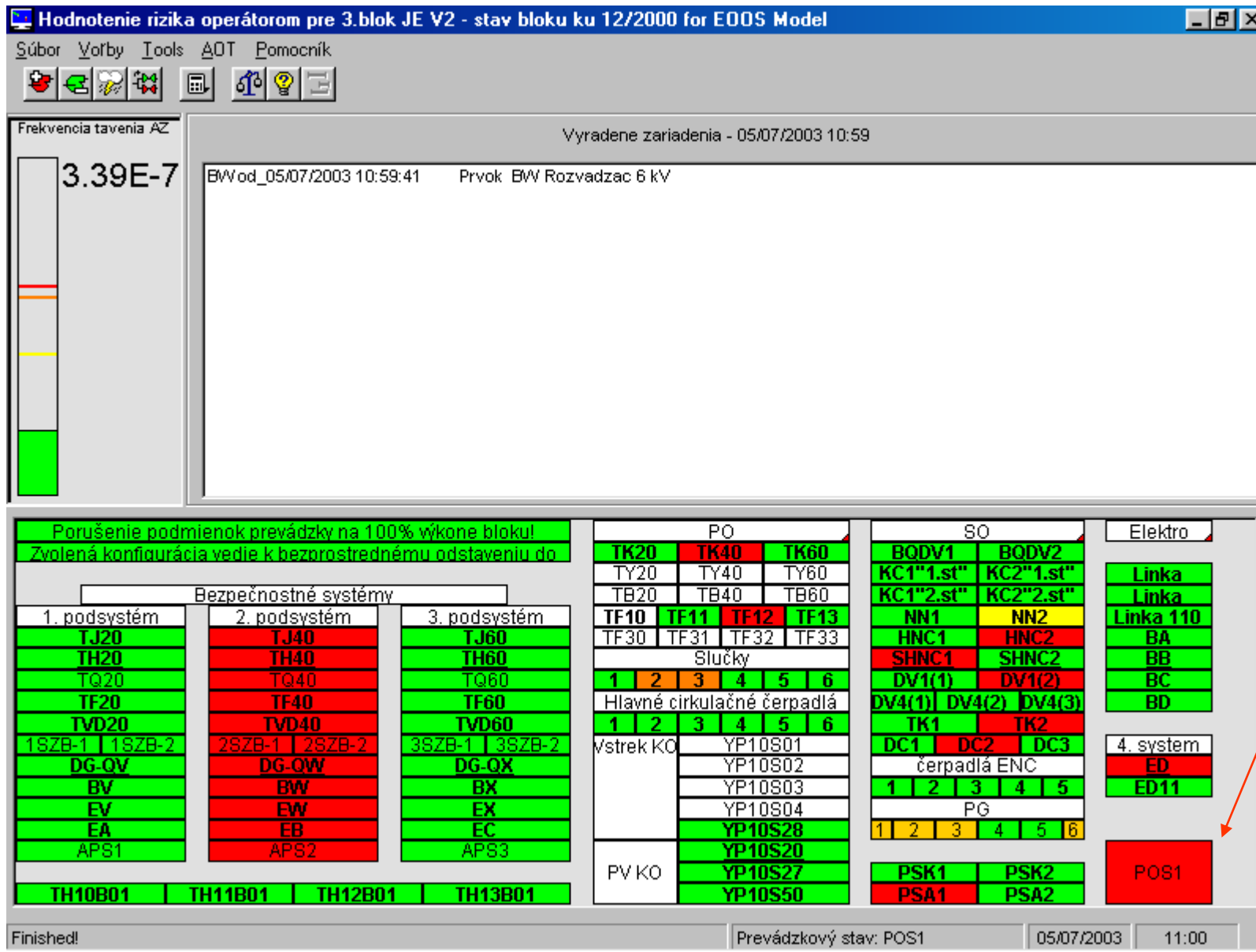
- point-in-time risk (CDF/ LERF)
- risk profile; cumulative risk
- Allowed Configuration Time
- safety function/ safety system status

The most popular riskmonitors

- „Equipment Out Of Service software“ (EOOS) – EPRI product, currently renamed to „Phoenix Risk Monitor“ (model format: CAFTA)
- „Safety Monitor“ developed by Sciencetech (model format WinNupra)
- „RiskSpectrum Riskwatcher“ developed by Lloyd's Register RiskSpectrum AB (model format RiskSpectrum PSA)

„EOMS“ risk monitor

Operators in control room

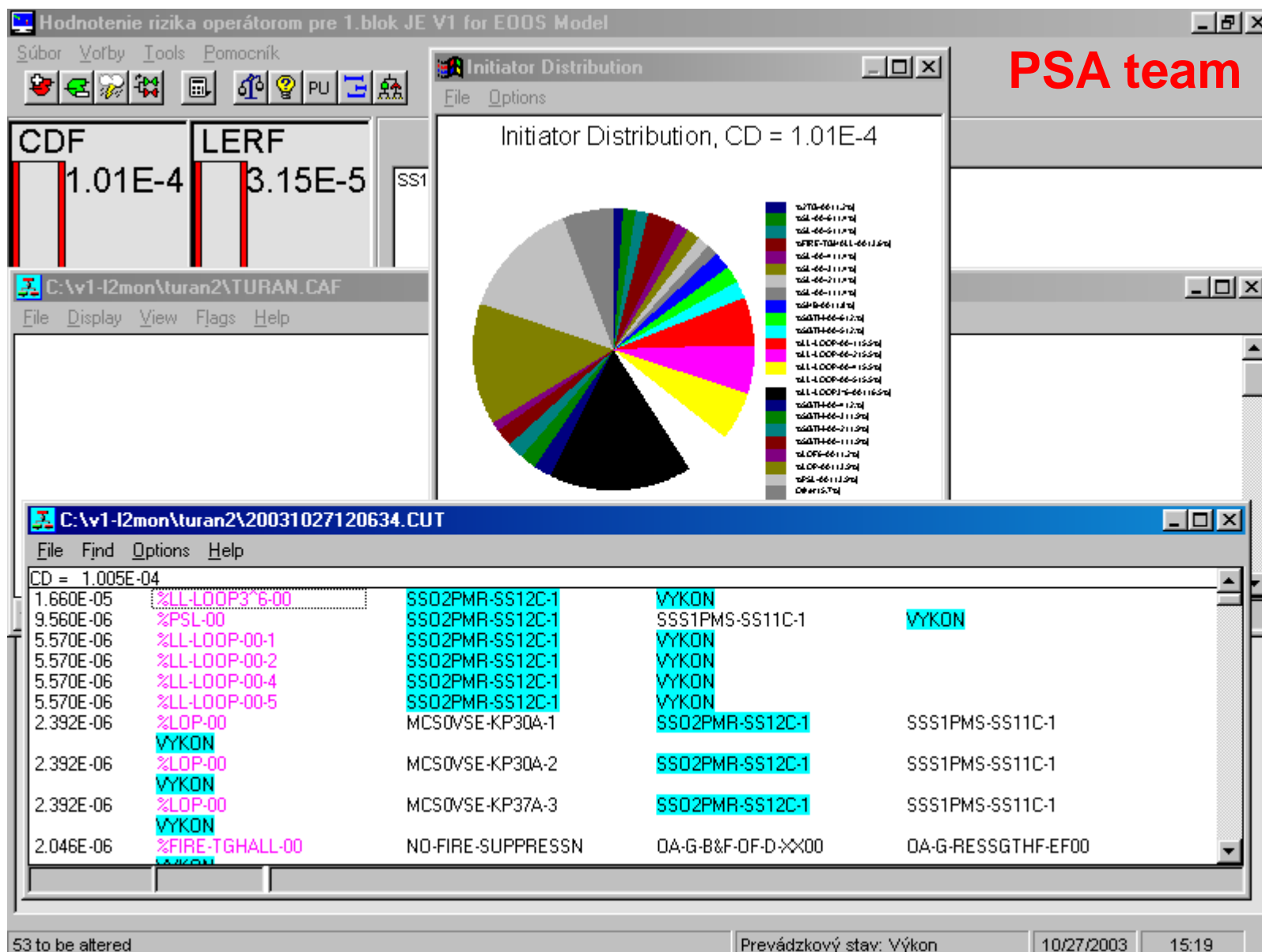


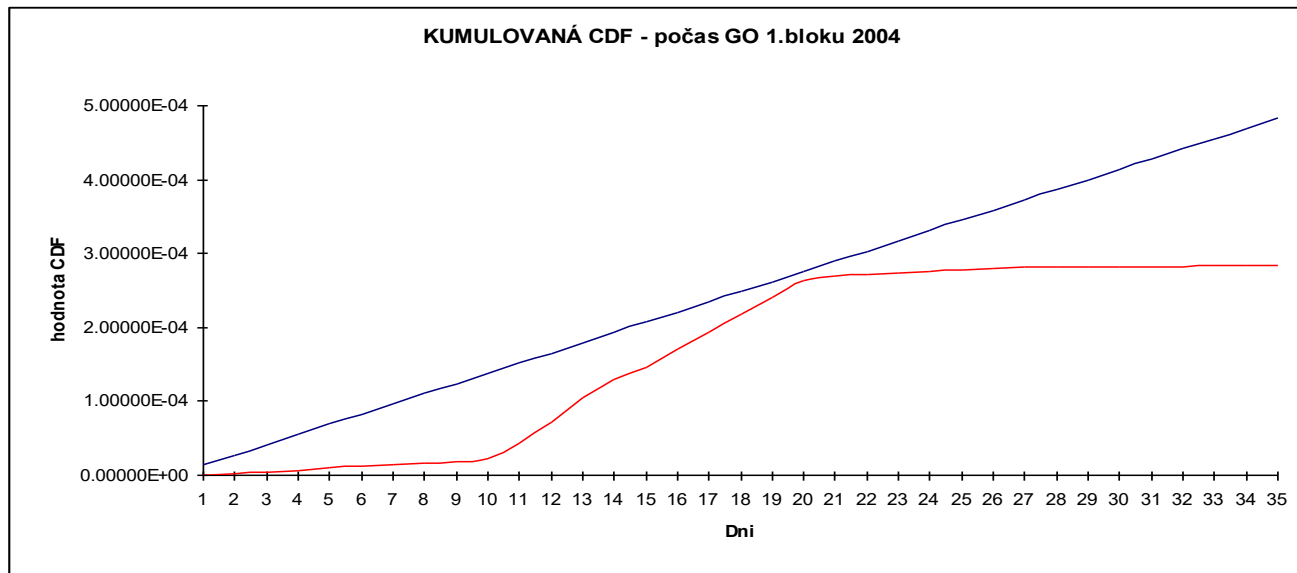
Plant
operational
state
indicator

„E00S“ risk monitor

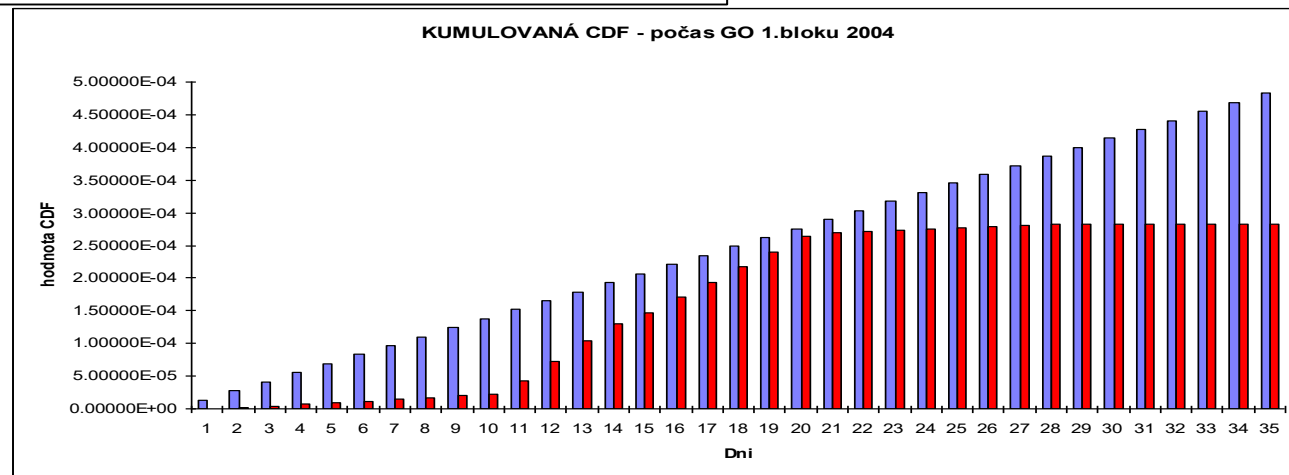
Analysis tools, reports

PSA team

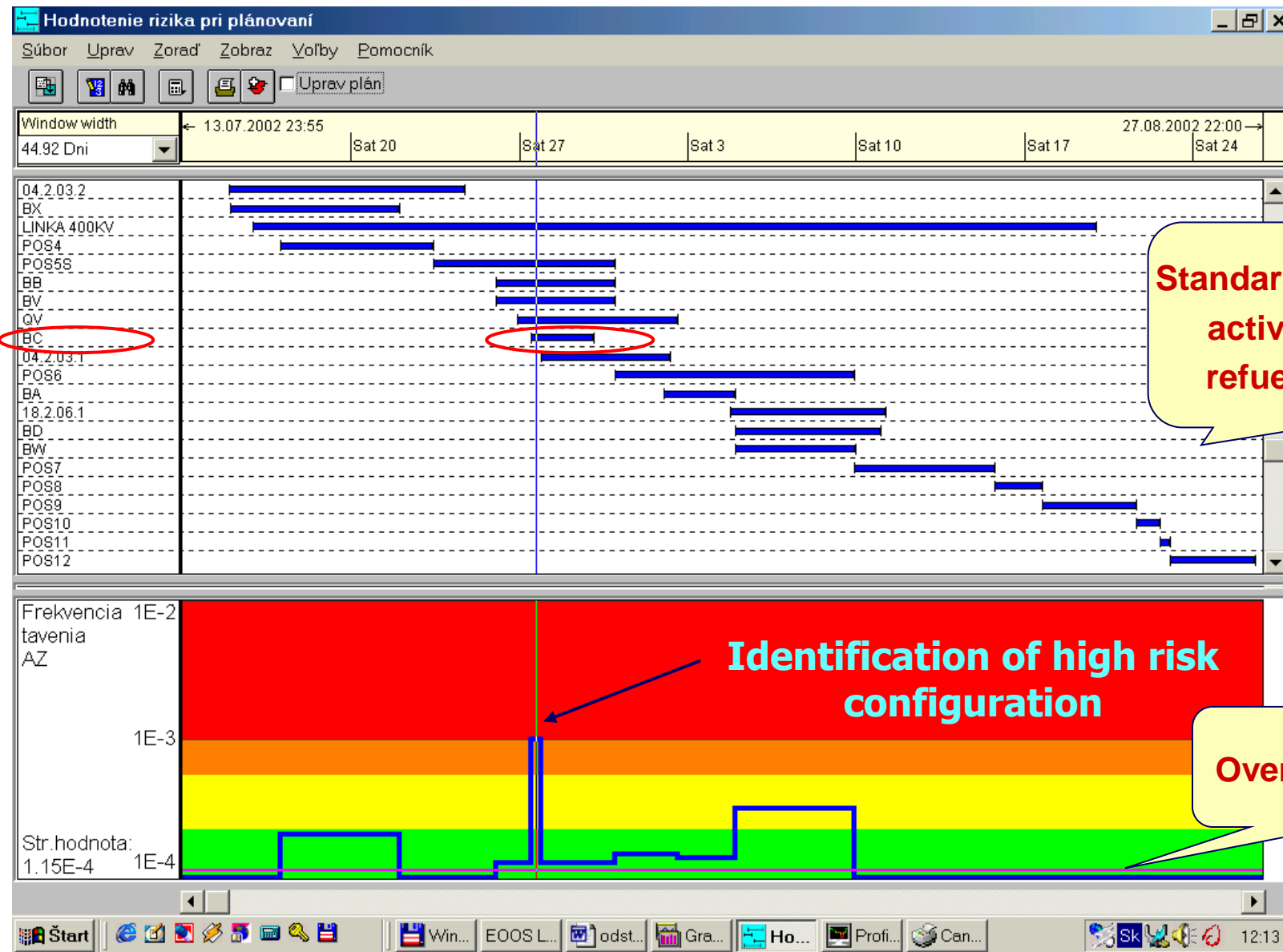




**Cumulative
CDF for whole
refuelling
outage/whole
year**



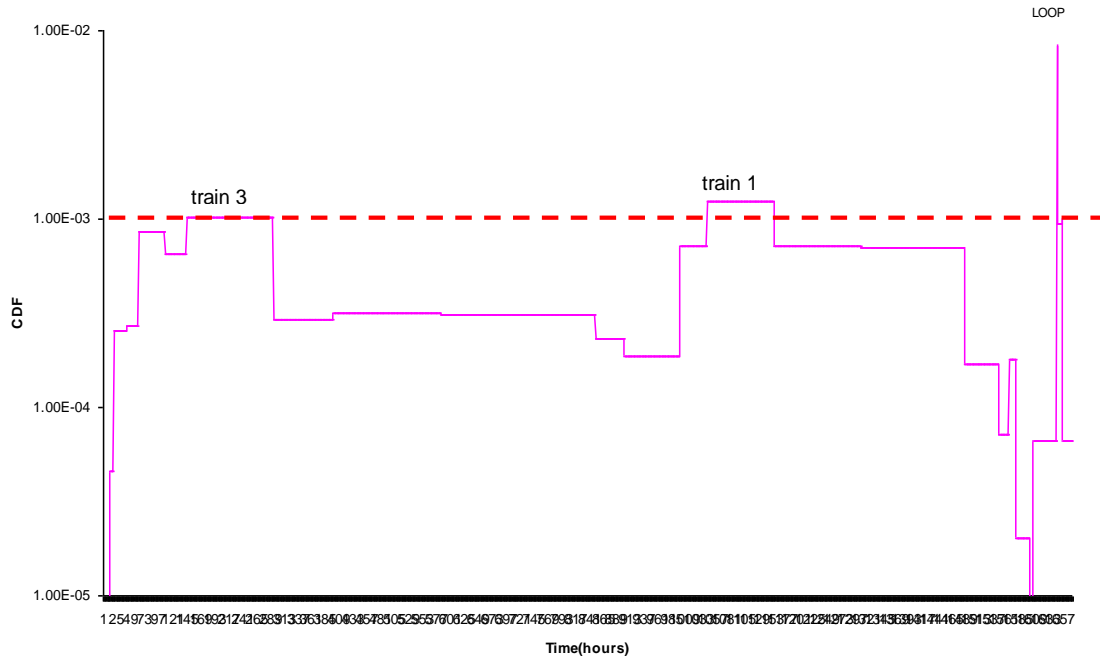
Maintenance team



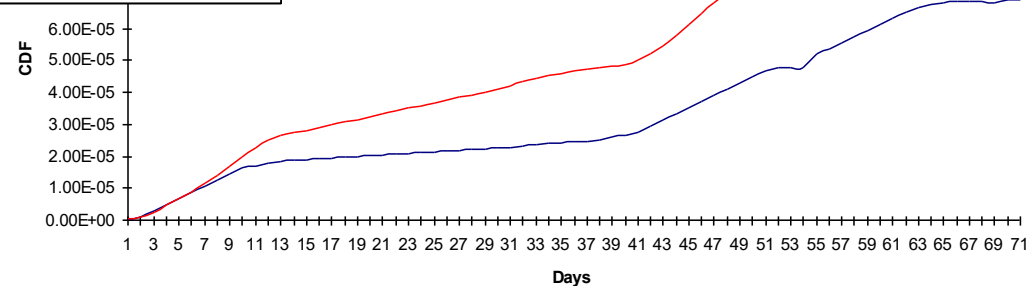
Maintenance team

Evaluation of the real risk profile during refuelling outage

Real Risk profile

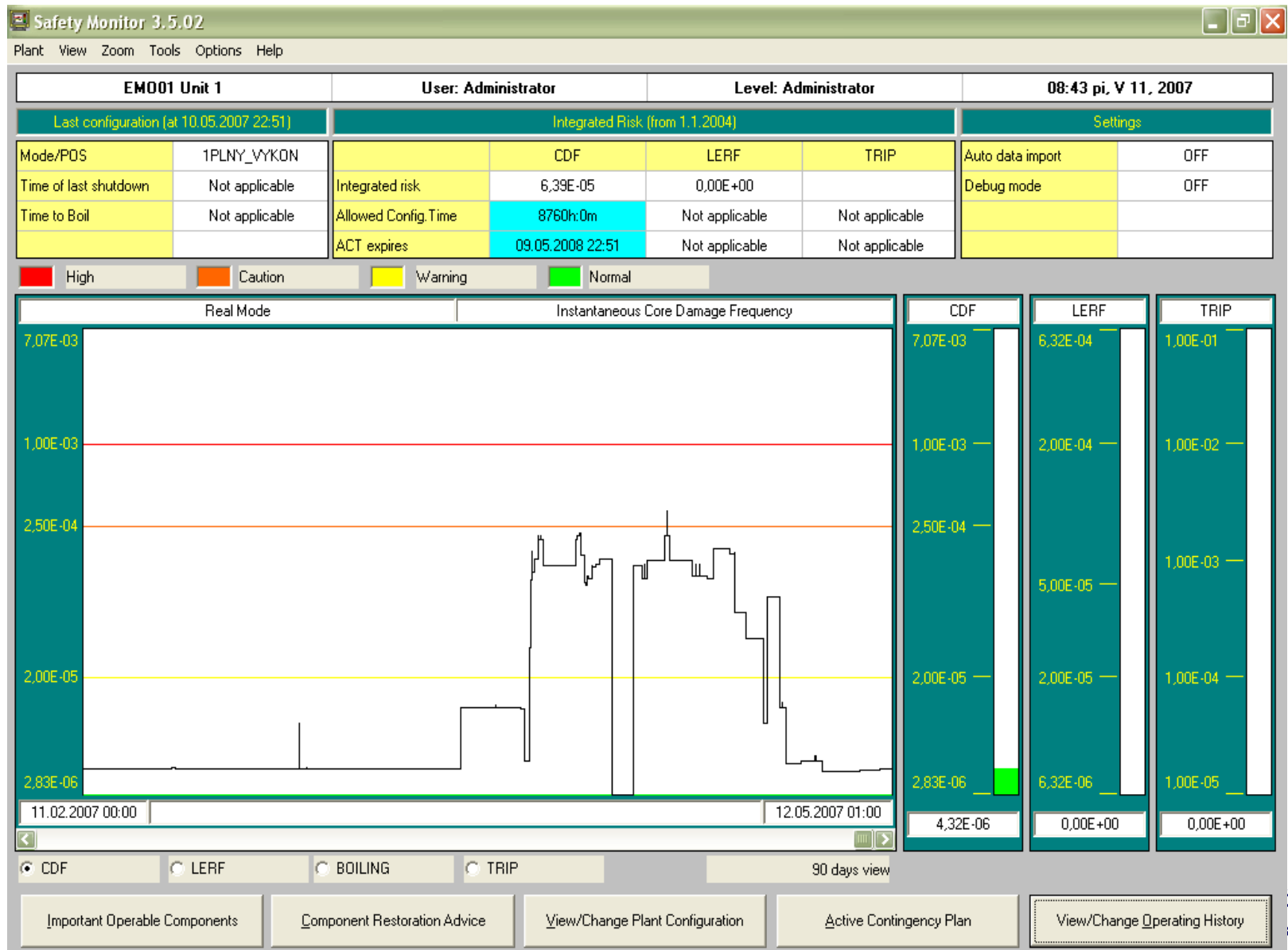


Cumulative CDF during refuelling outage



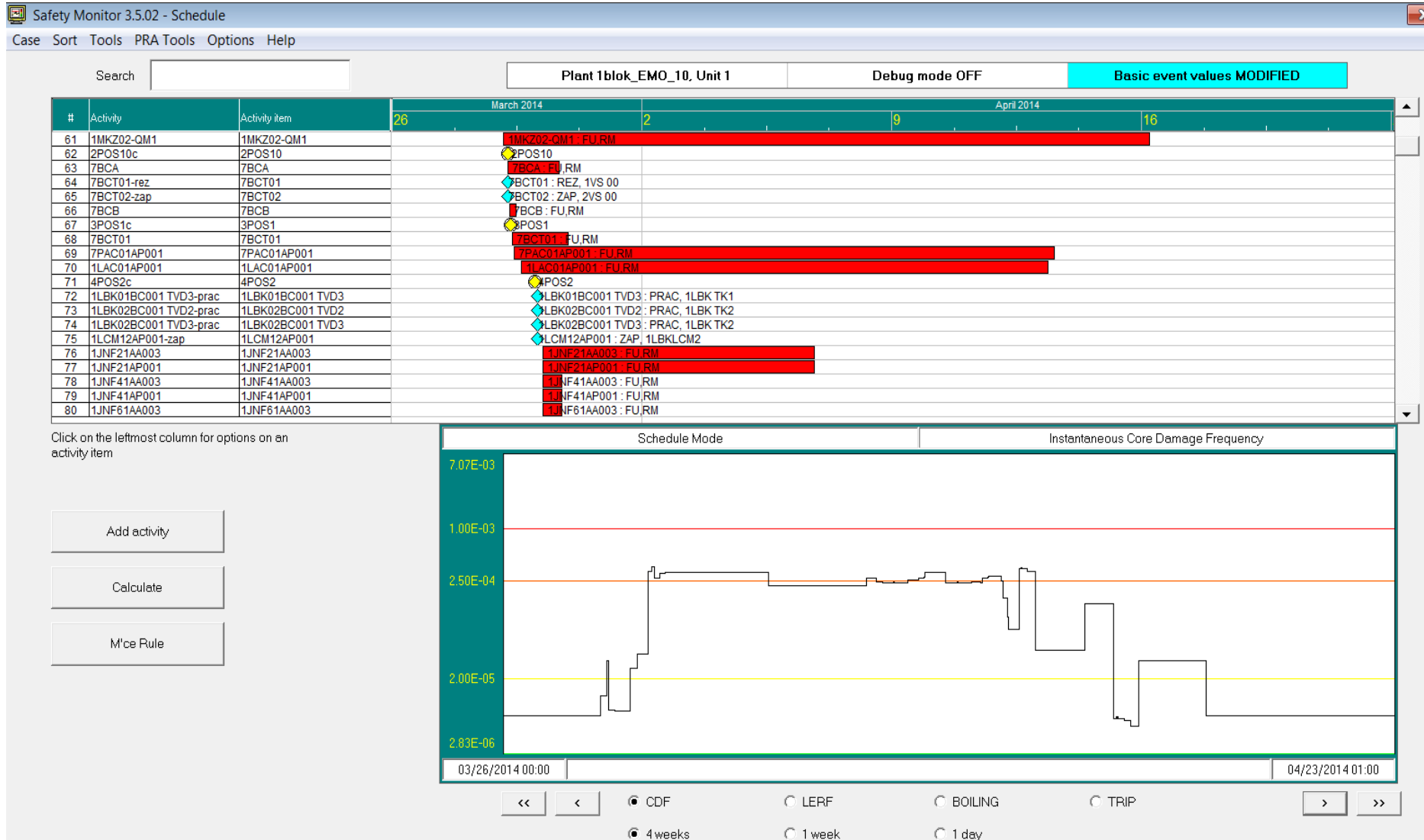
„Safety Monitor“ risk monitor

Use of SM in Real or Hypothetical Mode



„Safety Monitor“ risk monitor

Use of SM in Schedule Mode



„RiskSpectrum RiskWatcher”

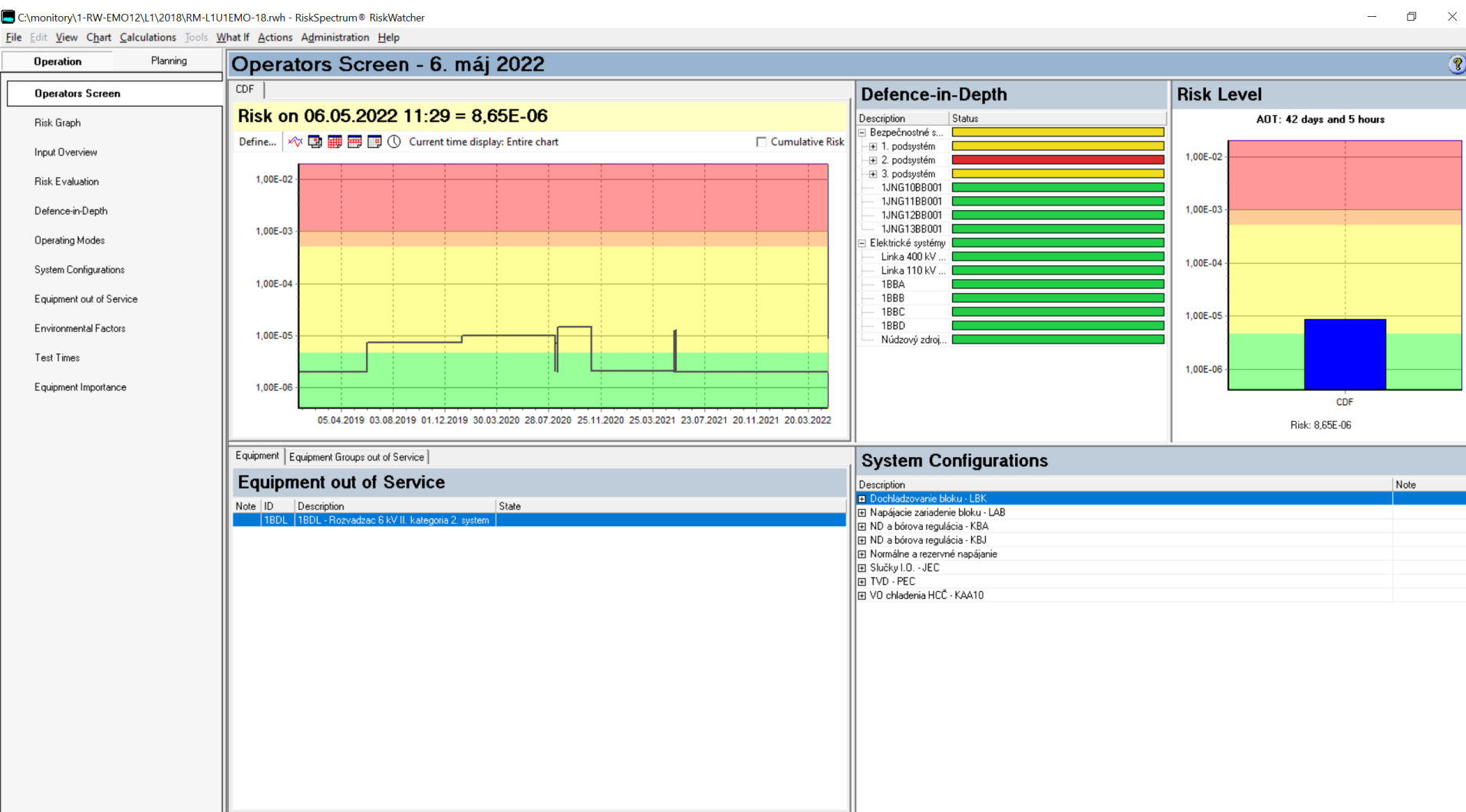
Two platforms:

➤ desktop version

➤ WEB version

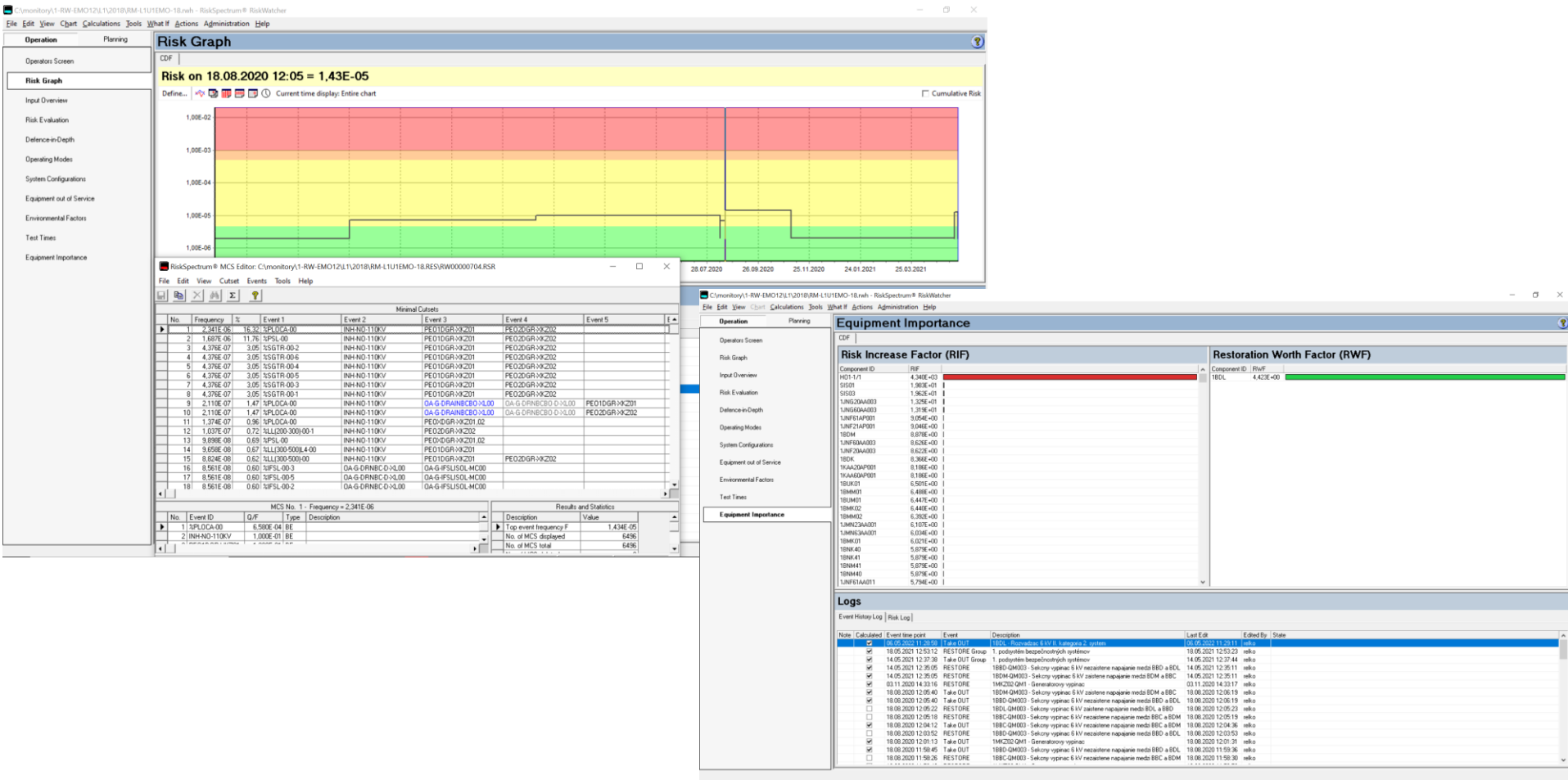
„RiskSpectrum RiskWatcher” - desktop

Operation



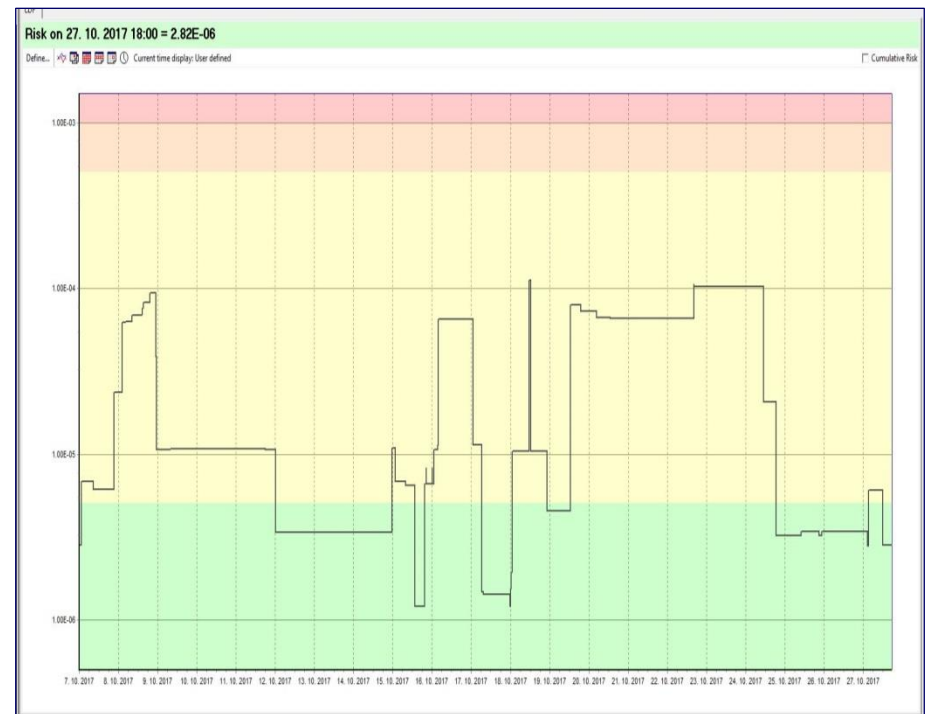
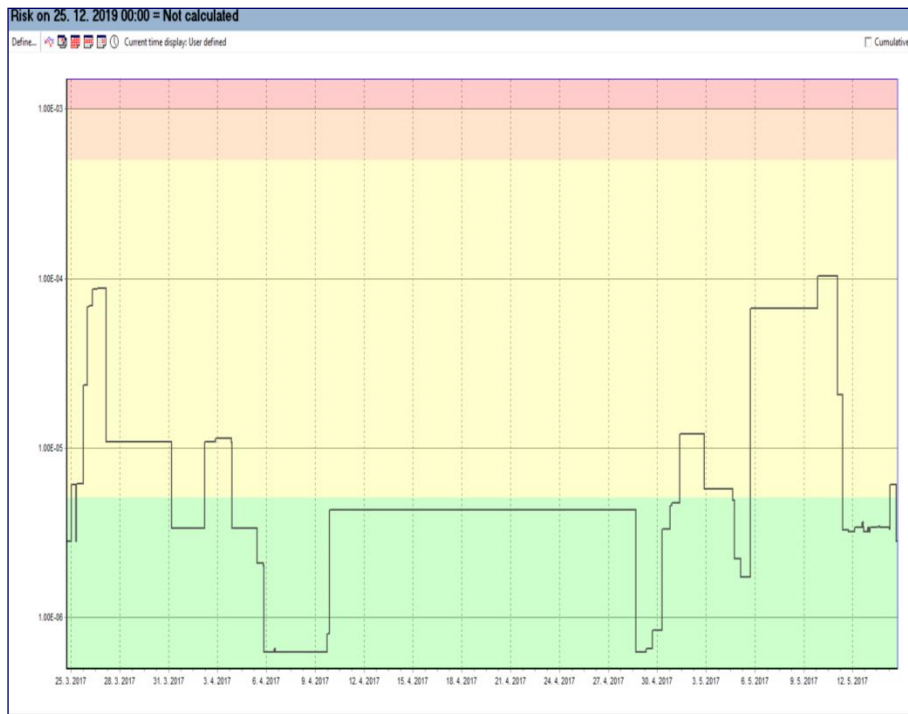
„RiskSpectrum RiskWatcher” - desktop

Operation



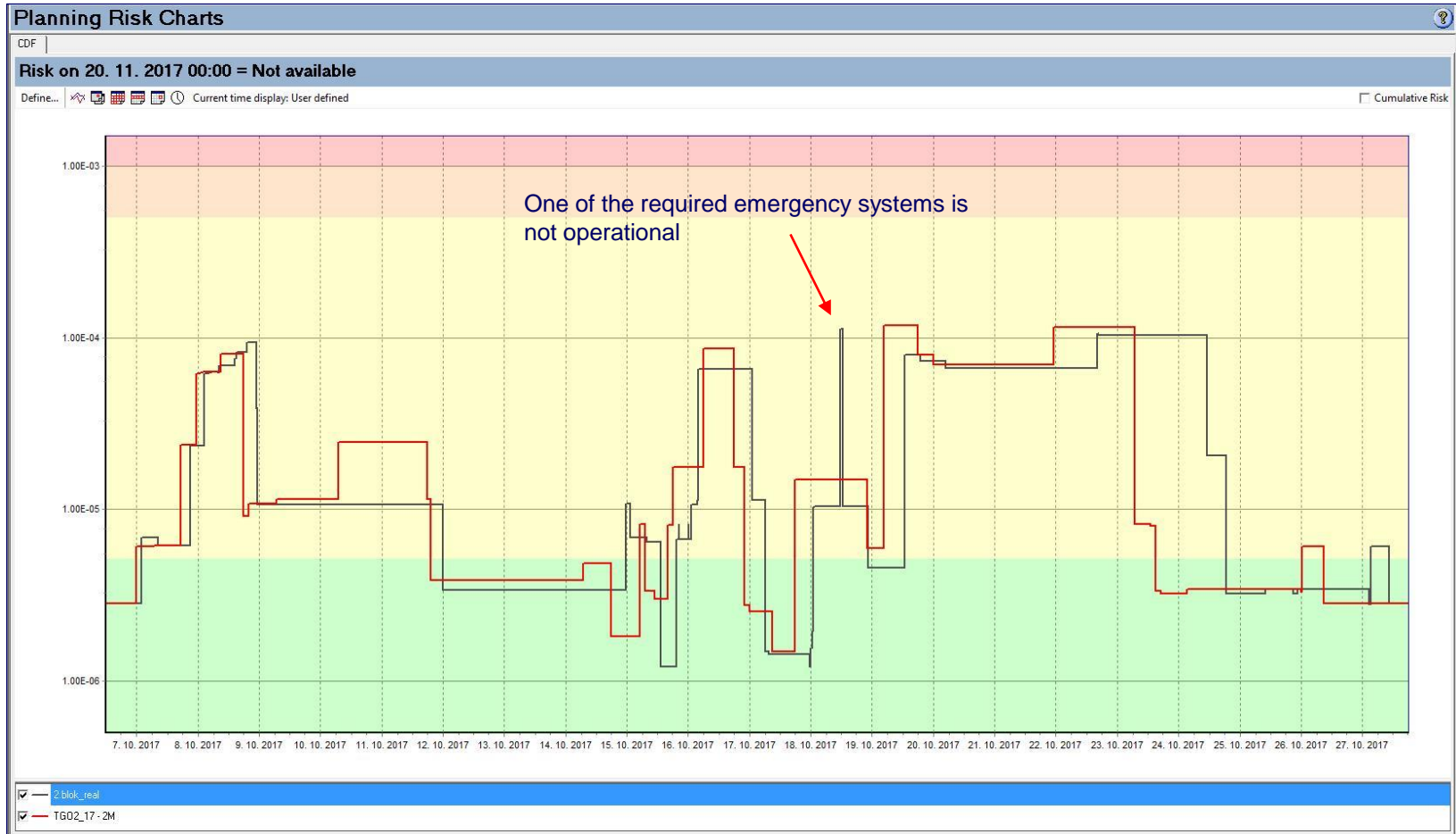
„RiskSpectrum RiskWatcher” - desktop

Planning



„RiskSpectrum RiskWatcher” - desktop

Planning



„RiskSpectrum RiskWatcher” - WEB

Online



Operating Mode: Full power mode
AOT: More than 30 days

Equipment out of Service

ID	State
ACP-DG01	FAILURE MODE

Level	Description	Attachment	Handled
1	OTS 4 - All text from the TS that is defined for the presentation as part of the OTS functionality (the document which defines the presentation of the OTS functionality)	Attachment	<input type="checkbox"/>
1	OTS 6 - All text from the TS that is defined for the presentation as part of the OTS functionality (the document which defines the presentation of the OTS functionality)	Attachment	<input type="checkbox"/>

Reference in Depth

Operational requirements				
Feedwater supply		Support Systems		
Emergency Feed Water System	Main Feed Water System	AC Power System	Component Cooling Water System	Service Water System
EFW-1		ACP-1	ACP-1	SWS-1
EFW-2		ACP-2	CCW-1	SWS-2
		ACP-3	CCW-2	
Safety requirements				
Core Cooling		Residual Heat Removal		
Emergency Core Cooling System	Emergency Feed Water System	Emergency Core Cooling System	Emergency Feed Water System	Residual Heat Removal System
ECC-1	EFW-1	ECC-1	EFW-1	RHR-1
ECC-2	EFW-2	ECC-2	EFW-2	RHR-2



or



2019-02-07 14:37:39

☒ CDF ☐ LERF

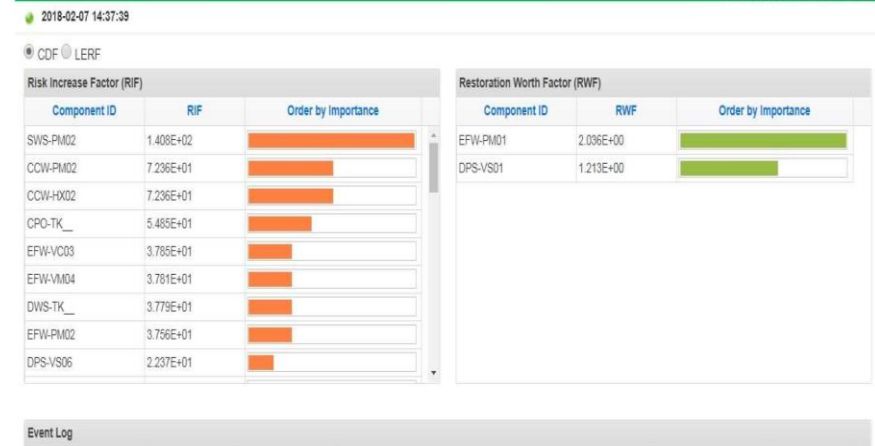
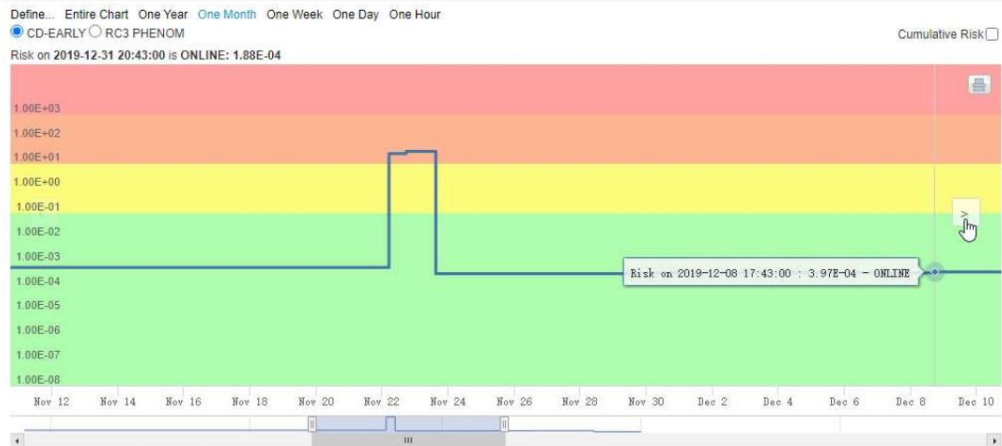
Risk Increase Factor (RIF)		
Component ID	RIF	Order by importance
SWIS-PM02	1.408E+02	
CCW-PM02	7.236E+01	
CCW-HX02	7.236E+01	
CPO-TK_	5.485E+01	
EFW-VC03	3.785E+01	
EFW-VM04	3.781E+01	
DWS-TK_	3.779E+01	
EFW-PM02	3.756E+01	
DPS-VS06	2.237E+01	

Restoration Worth Factor (RWF)		
Component ID	RWF	Order by importance
EFW-PM01	2.036E+00	
DPS-VS01	1.213E+00	

Event Log						
Event Time Point	Event	ID	Description	State	Last Edit Time	Edited By
2018-04-02 14:37:39	TAKE OUT	ACP-DG01	Diesel generator in standby supplying power to bu		2018-11-19 10:31:37	administrator
2018-03-28 14:37:39	Config ON	CCW-2	Component Cooling Water System train 2 in opera		2018-11-16 15:45:38	administrator
2018-02-28 14:37:39	RESTORE	EFW-PM01	Emergency Feed Water System pump 1		2018-11-16 15:43:00	administrator
2018-02-28 14:37:39	RESTORE	DPS-VS01	Depressurisation System Pressure relief valve 1		2018-11-16 15:43:00	administrator
2018-02-07 14:37:39	TAKE OUT	EFW-PM01	Emergency Feed Water System pump 1		2018-11-16 15:42:40	administrator
2018-01-31 14:37:39	TAKE OUT	DPS-VS01	Depressurisation System Pressure relief valve 1		2018-11-16 15:40:21	administrator
2018-01-10 14:37:39	RESTORE	ACP-DG01	Diesel generator in standby supplying power to bu		2018-11-16 15:39:54	administrator
2018-01-04 14:37:39	TAKE OUT	ACP-DG01	Diesel generator in standby supplying power to bu		2018-11-16 15:38:00	administrator
2018-01-01 14:37:39	EF ON	WINTER	Winter conditions (November - April)		2018-11-15 14:38:02	SYSTEM

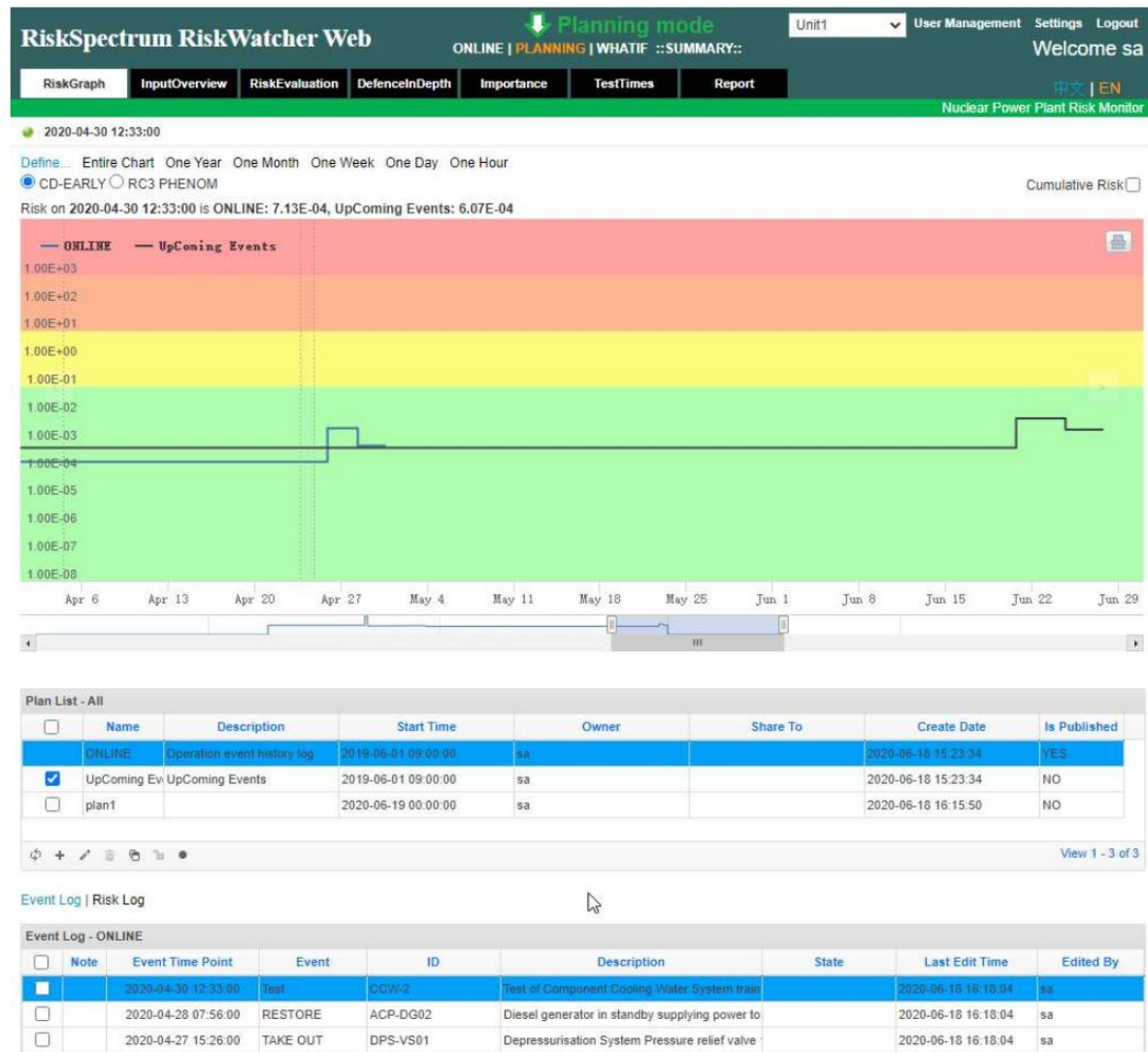
„RiskSpectrum RiskWatcher” - WEB

Online



„RiskSpectrum RiskWatcher” - WEB

Planning



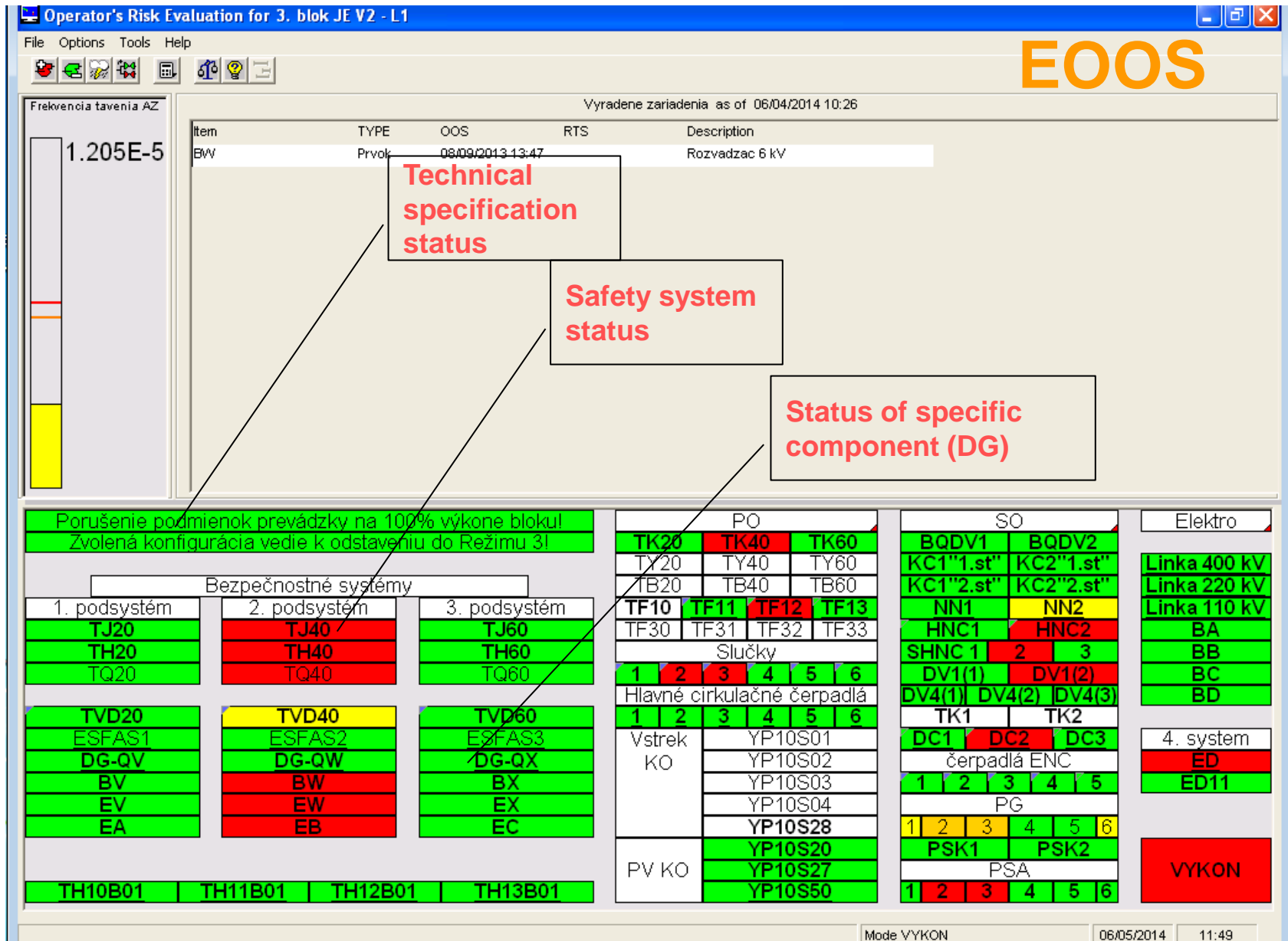
Defence-in-Depth structures – qualitative part of Risk monitors

- Provide **qualitative** risk assessment
- Provide instantaneous (visual) information about the availability of systems, subsystems and components, safety functions.
- **Illustrate relations and dependencies between systems, etc.**

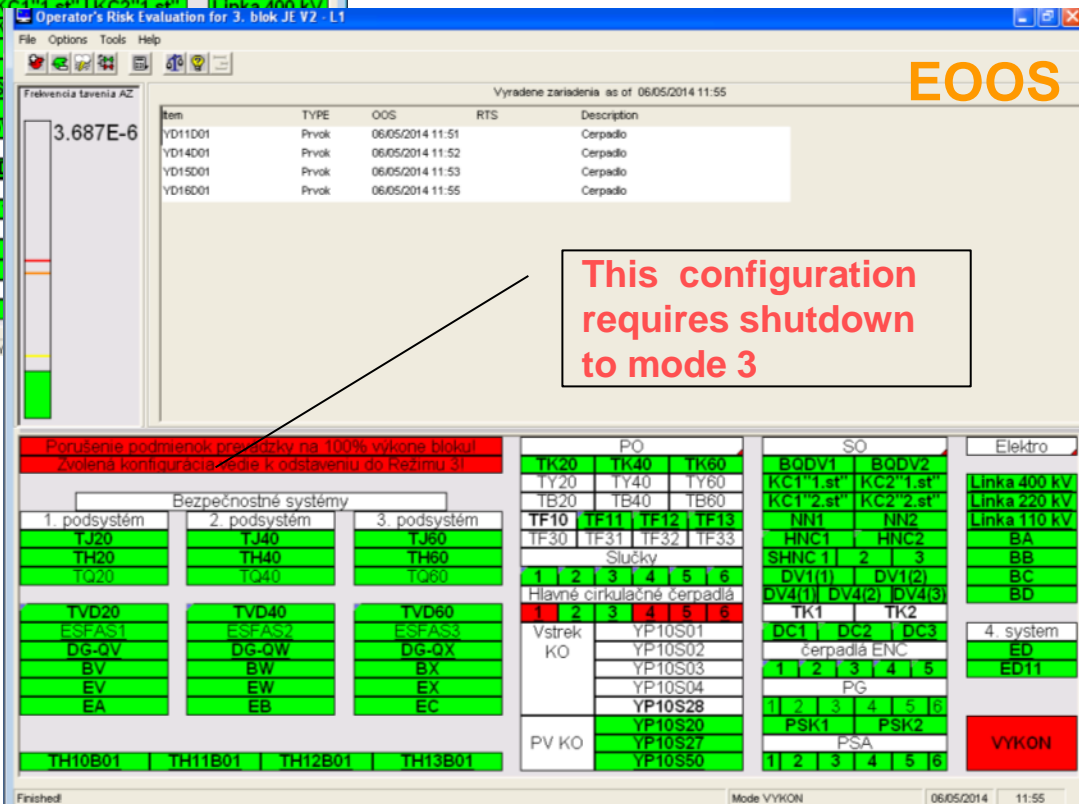
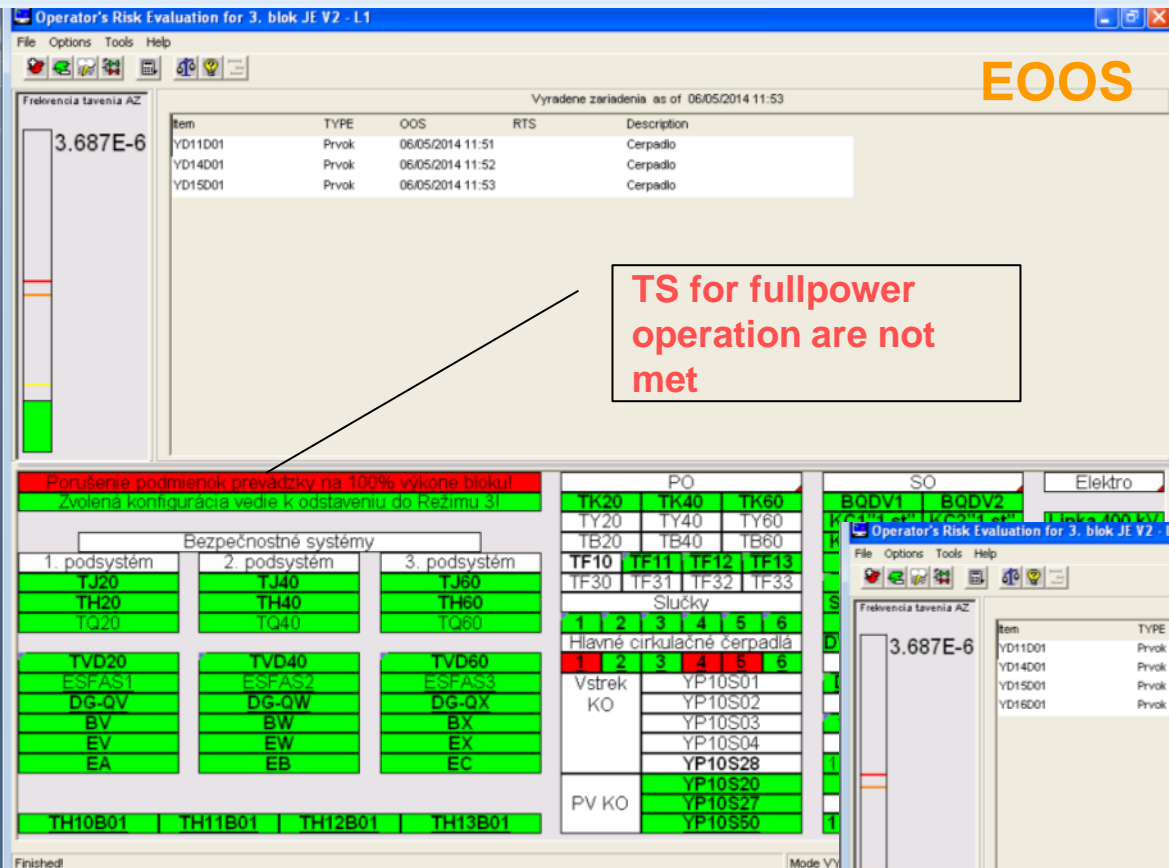
Examples of Ways to Use DiD Panel Displays

Item Monitored	What the Colors Mean		
System status	Red	=	System unavailable
	Yellow/Orange	=	System partially available
	Green	=	System available
Safety function status	Red	=	Safety function requirements not met
	Yellow/Orange	=	Safety function requirements partially met
	Green	=	Safety function requirements met
Compliance with technical specifications	Red	=	Plant is not in compliance
	Yellow/Orange	=	Plant is partially in compliance
	Green	=	Plant is in compliance

Examples of Defence-in-Depth structures



Examples of Defence-in-Depth structures



Examples of Defence-in-Depth structures

C:\Program Files (x86)\RiskSpectrum\RiskWatcher\Sample\sample.rwh - RiskSpectrum® RiskWatcher - TRIAL MODE

RiskWatcher desktop

File Edit View Chart Calculations Tools Actions Administration Help

Operation

Operators Screen

Risk Graph

Defence-in-Depth

Operating Modes

System Configurations

Taken Out of Service

Environmental Factors

Test Times

Component Importance

Planning

Operators Screen - 6. jún 2014

Defence-in-Depth

Description	Status
Operational requirements	
Feedwater supply	
Emergency Feed Water System	
Emergency Feed Water System tra...	
Emergency Feed Water System tra...	
Main Feed Water System	
Support Systems	
AC Power System	
AC Power System train 1	
AC Power System train 2	
AC Power System train 3	
Component Cooling Water System	
Component Cooling Water System t...	
Component Cooling Water System t...	
Service Water System	
Service Water System train 1	
Service Water System train 2	
Safety requirements	
Core Cooling	
Emergency Core Cooling System	
Emergency Core Cooling System tr...	
Emergency Core Cooling System tr...	
Emergency Feed Water System	
Emergency Feed Water System tra...	
Emergency Feed Water System tra...	
Residual Heat Removal	
Emergency Core Cooling System	
Emergency Core Cooling System tr...	
Emergency Core Cooling System tr...	
Emergency Feed Water System	
Emergency Feed Water System tra...	
Emergency Feed Water System tra...	
Residual Heat Removal System	
Residual Heat Removal System tra...	
Residual Heat Removal System tra...	

Components Out of Service

Note	ID	Description	State
	EFW-PM01	Emergency Feed Water System pump 1	

The status of operational requirements

Safety function status



Examples of Defence-in-Depth structures

RiskSpectrum RiskWatcher Web

OTs_1

User Management

Settings

Logout

ONLINE | PLANNING | WHATIF

Welcome sa

OperatorScreen

RiskGraph

InputOverview

DefenceInDepth

Importance

Report

EN

Help

Nuclear Power Plant Risk Monitor

2019-09-05 17:03:39

Defence in Depth | Defence in Depth Over Time

RiskWatcher WEB

Defence in Depth [\[Hide OTS\]](#)

Feedwater supply		Operational requirements		
Emergency Feed Water System	Main Feed Water System	AC Power System	Component Cooling Water System	Service Water System
EFW-1		ACP-1	ACP-1	SWS-1
EFW-2		ACP-2	CCW-1	SWS-2
		ACP-3	CCW-2	

Core Cooling		Safety requirements		
Emergency Core Cooling System	Emergency Feed Water System	Emergency Core Cooling System	Emergency Feed Water System	Residual Heat Removal System
ECC-1	EFW-1	ECC-1	EFW-1	RHR-1
ECC-2	EFW-2	ECC-2	EFW-2	RHR-2

The status of operational requirements

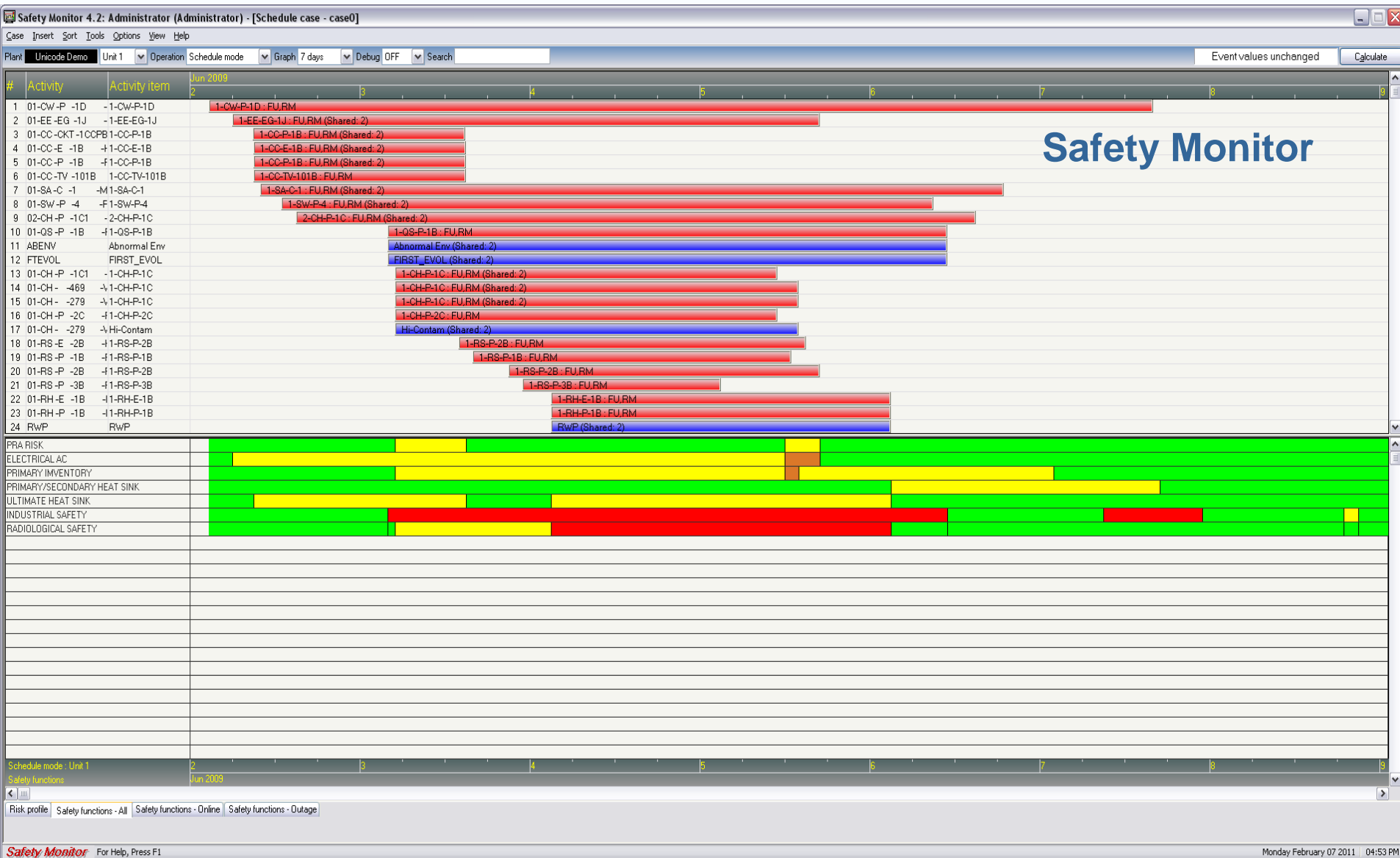
OTS

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The status of Safety requirements/Safety systems

Event Log							
Note	Event Time Point	Event	ID	Description	State	Last Edit Time	Edited By
	2019-09-08 17:03:39	Config. ON	MFWP2	Main Feed Water System P2 in operation		2019-12-18 18:29:20	sa
	2019-09-08 17:03:39	Config. ON	MFWP3	Main Feed Water System P3 in operation		2019-12-18 18:29:20	sa
	2019-09-05 17:03:39	TAKE OUT	ACP-DG01	Diesel generator in standby supplying power to b	FAILURE MODE 1	2019-12-16 15:15:26	sa
	2019-09-01 17:03:39	Test	ECC-1	Test of Emergency Core Cooling System train 1		2019-12-16 15:15:26	SYSTEM
	2019-09-01 17:03:39	Test	CCW-2	Test of Component Cooling Water System train 2		2019-12-16 15:15:26	SYSTEM
	2019-09-01 17:03:39	Test	CCW-1	Test of Component Cooling Water System train 1		2019-12-16 15:15:26	SYSTEM
	2019-09-01 17:03:39	Test	ACP-3	Test of AC Power System train 3		2019-12-16 15:15:26	SYSTEM
	2019-09-01 17:03:39	Test	ACP-2	Test of AC Power System train 2		2019-12-16 15:15:26	SYSTEM
	2019-09-01 17:03:39	Test	ACP-1	Test of AC Power System train 1		2019-12-16 15:15:26	SYSTEM
	2019-09-01 17:03:39	EF ON	SUMMER	Summer conditions (May - October)		2019-12-16 15:15:26	SYSTEM

Examples of Defence-in-Depth structures



Outage Risk Management General Practice

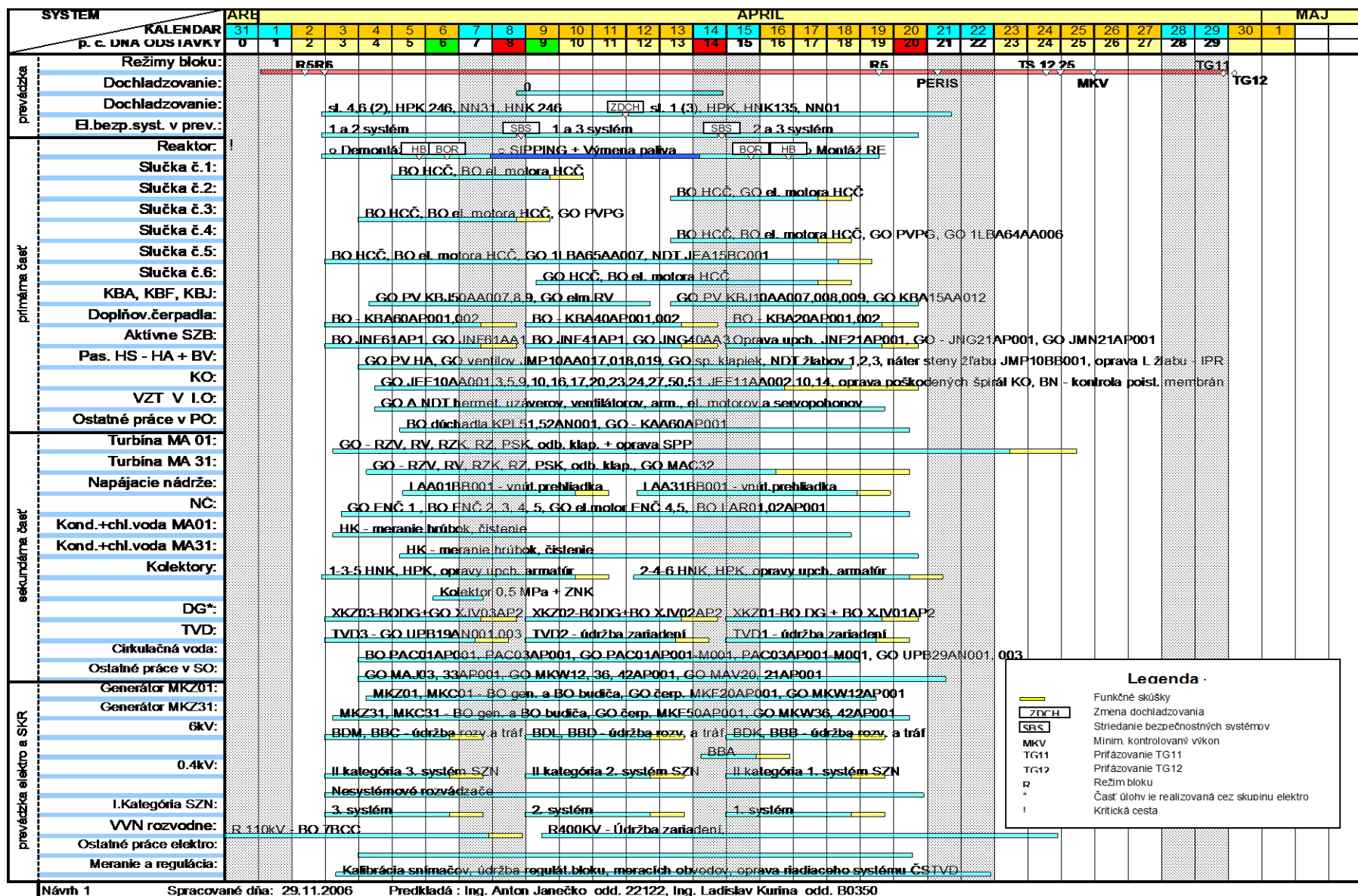
- Preparation of preliminary outage schedule.
- Outage risk profile calculation and identification of the high risk plant configuration.
- Discussion of findings and development of the reviewed outage schedule.
- Final outage risk profile calculation and outage schedule authorization by safety department.

Outage Risk Management General Practice

An example of specific steps of the refuelling outage analysis using Risk monitor software:

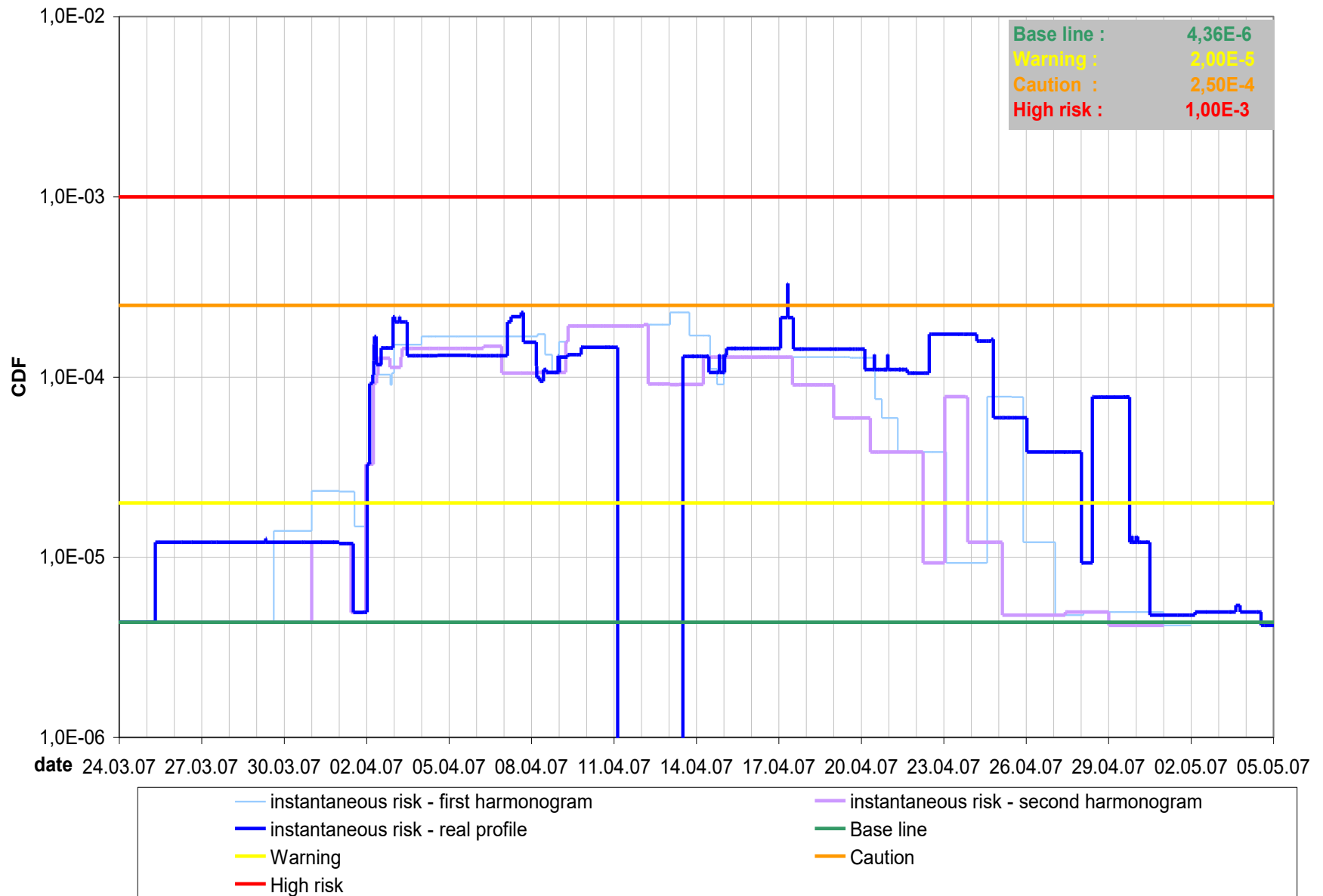
1. Preparation of the outage schedule
2. 1st preliminary analysis of the refuelling outage – eight months before outage
3. 2nd preliminary analysis of the refuelling outage – four months before outage (if necessary)
4. 3rd preliminary analysis of the refuelling outage – two months before outage – the result is sent also to regulatory authority
5. daily risk profile evaluation during the refuelling outage + final real risk profile for whole refuelling outage

Preliminary refuelling outage schedule



Outage Risk Management General Practice

Planning Risk profiles and Real profile comparison for outage at Unit 1 NPP Mochovce



Typical Reasons for Using a Risk Monitor

- **Apply a risk-informed approach to managing plant operational safety**
- **Schedule maintenance to avoid peaks in the risk**
- **Achieve greater flexibility in plant operation**
- **Provide justification for carrying out more maintenance on-line**
- **Get information on component restoration/ importance during maintenance**
- **Address US NRC Maintenance Rule**

Using of risk monitor for risk informed decision making – benefits

- PSA methodology via risk monitor can be used by the NPP staff **without detailed probabilistic knowledge** but on the other hand with detailed deterministic knowledge. Such situation creates good assumptions for integrated risk informed decision making.
- Based on Configuration Risk Management the risk profile of the plant can be optimized and minimized.
- High risk plant configurations can be identified and removed from the maintenance schedule program.
- Cumulative Risk of NPPs is reduced to the minimum.

References

- IAEA, SSG-3 '*Development and Application of Level-1 PSA*', 2010
- IAEA, OECD NEA, 'WGRisk, *Risk Monitors: The State of the Art in their Development and Use at Nuclear Power Plants*' A/CSNI/R(2004)20, OECD/NEA, Paris, (2004)
- IAEA-TECDOC-1101, '*Framework for a Quality Assurance Programme for PSA*', (1999).