

International Atomic Energy Agency

P8: Risk Monitoring and Managing Risk Configuration

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Application of Level 1 Probabilistic Safety Assessment

Bangkok, Thailand 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)

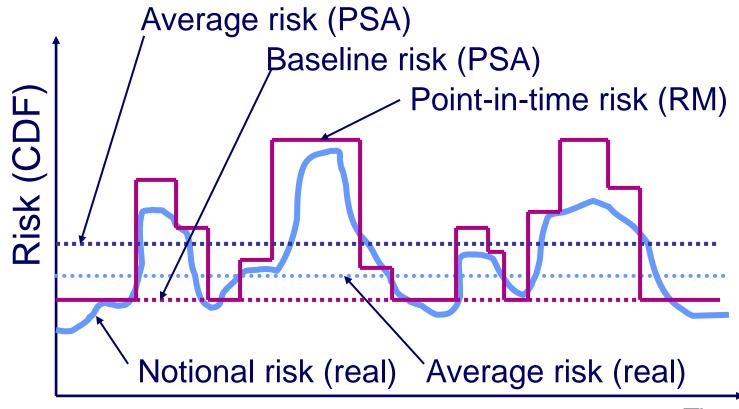


Typical Risk Monitor functions

- 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



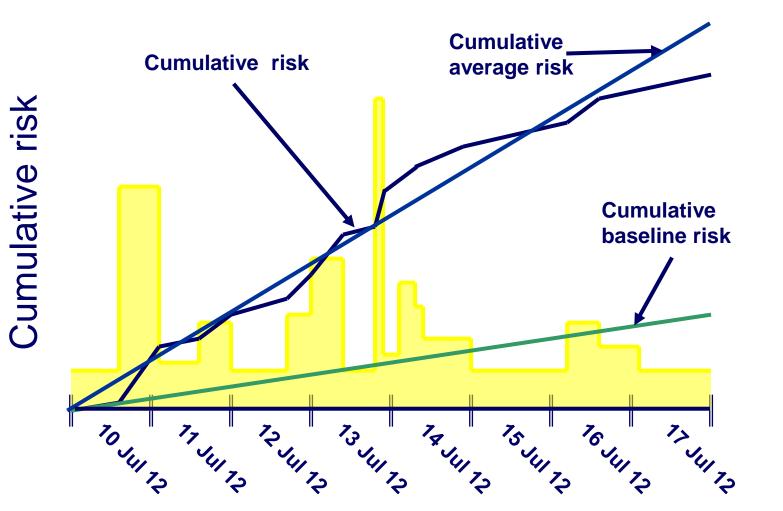
Plant risk



Time



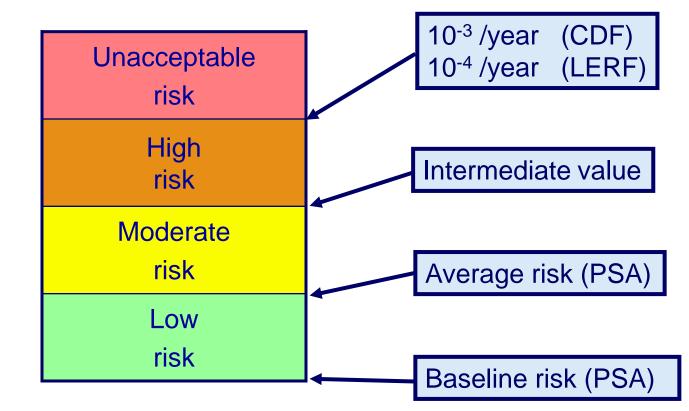
Cumulative Risk





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
- 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

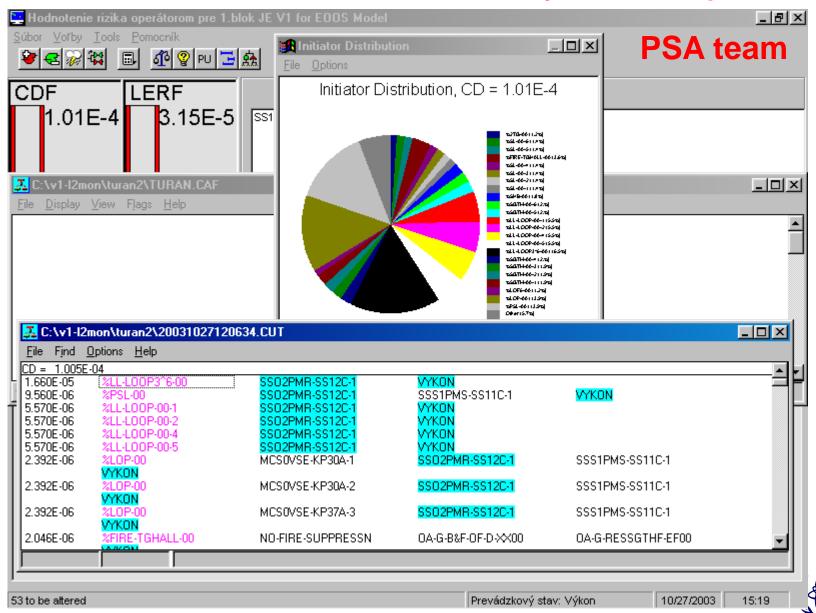
- "Equipment Out Of Service software" (EOOS) EPRI product, currently renamed to "Phoenix Risk Monitor" (model format: CAFTA)
- Safety Monitor" developed by Scientech (model format WinNupra)
- "RiskSpectrum Riskwatcher" developed by Lloyd's Register RiskSpectrum AB (model format RiskSpectrum PSA)

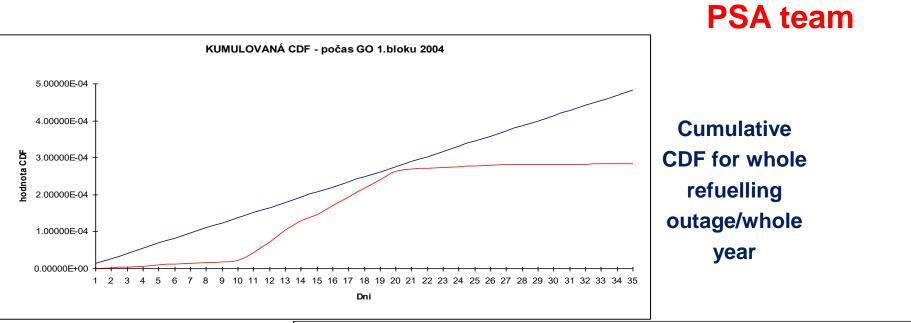


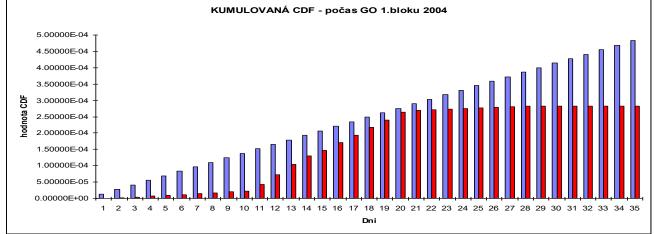
Operators in control room

🙀 Hodnotenie rizika operátorom pre 3.blok JE V2 - stav bloku k	ku 12/2000 for EOOS Model	
<u>S</u> úbor <u>V</u> oťby <u>T</u> ools <u>A</u> OT <u>P</u> omocník		
Sel		
Frekvencia tavenia AZ Vy	yradene zariadenia - 05/07/2003 10:59	
3.39E-7 BW od_05/07/2003 10:59:41 Prvok BW Rozv	vadzac 6 kV	Plant operational state
Porušenie podmienok prevádzky na 100% výkone bloku!	PO SO Elektro	indicator
Zvolená konfigurácia vedie k bezprostrednému odstaveniu doBezpečnostné systémy1. podsystém2. podsystémTJ20TJ40TJ60TH20TH40TH60TQ20TQ40TQ60TF20TF40TF60TVD20TVD40SZB-11SZB-11SZB-2SZZB-1DG-QVDG-QWBVBVBWBXEVEWEXEAEBECAPS1TH11B01TH12B01TH13B01	TK20 TK40 TK60 BQDV1 BQDV2 TY20 TY40 TY60 KC1"1.st" KC2"1.st" Linka TB20 TB40 TB60 KC1"2.st" KC2"2.st" Linka TF10 TF11 TF12 TF13 NN1 NN2 BA TF30 TF31 TF32 TF33 Slučky BA BB Slučky SHNC1 SHNC2 BB BC BA Slučky SHNC1 SHNC2 BB BC BD Hlavné cirkulačné čerpadlá DV1(1) DV4(2) DV4(3) BD BD YP10S01 Čerpadlá ENC 1 Z 3 4 5 6 YP10S03 T Z 3 4 5 6 ED ED	Agency
Finished	Prevádzkový stav: POS1 05/07/2003 11:00	

Analysis tools, reports

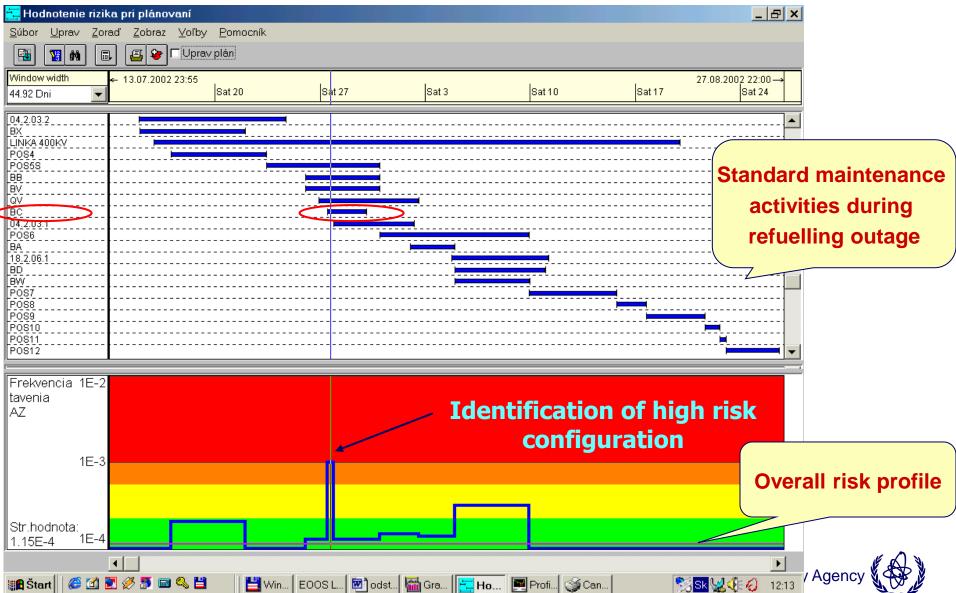






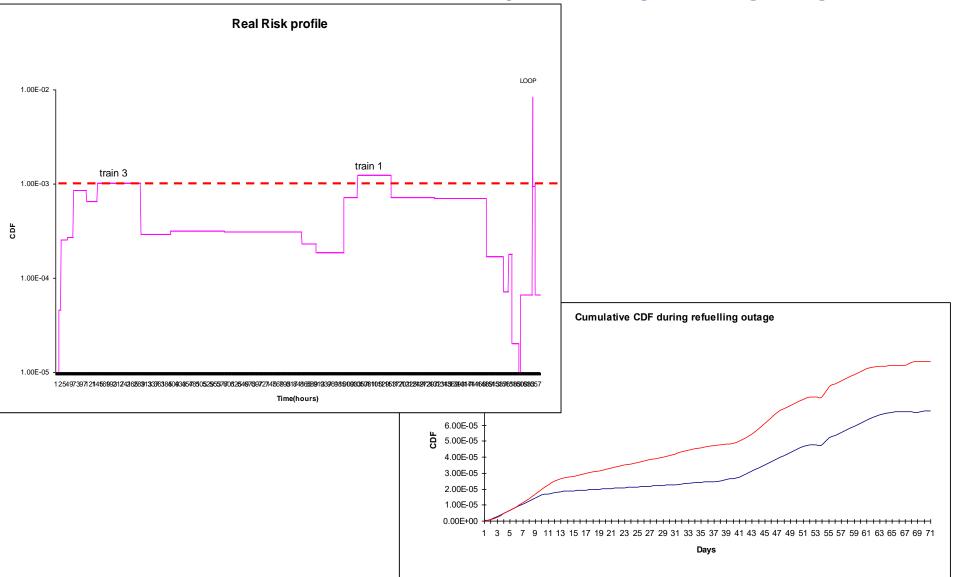
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Maintenance team



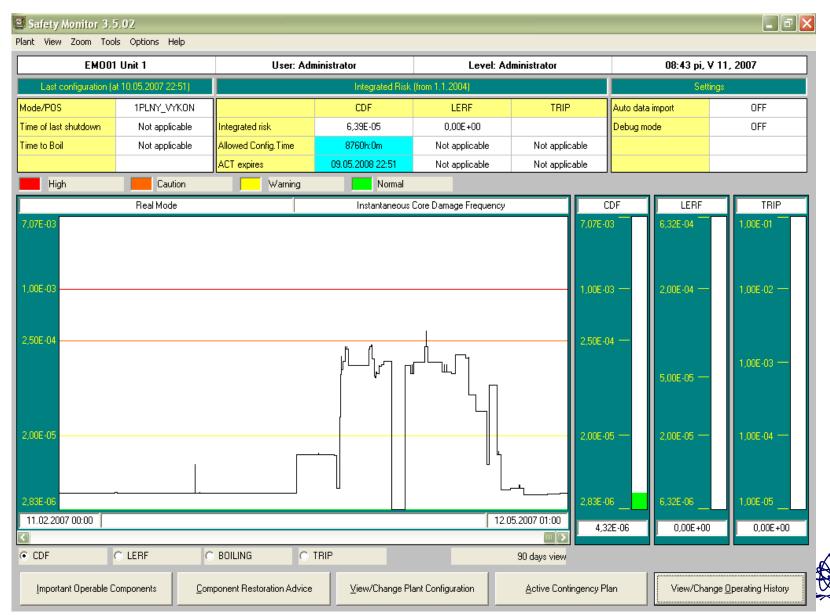
Maintenance team

Evaluation of the real risk profile 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

Search		Plant 1blok_EMO_10, Unit 1	Debug mode OFF	Basic event values MODIFIED
		March 2014		ril 2014
# Activity	Activity item	26	. 9	16
61 1MKZ02-QM1	1MKZ02-QM1	1MKZ02-QM1 : FU,RM		
62 2POS10c	2POS10	O2POS10		
63 7BCA	7BCA	7BCA:FU,RM		
64 7BCT01-rez	7BCT01	BCT01 : REZ, 1VS 00		
65 7BCT02-zap	7BCT02	BCT02 : ZAP, 2VS 00		
66 7BCB	7BCB	7BCB : FU,RM		
67 3POS1c	3POS1	OppoS1		
68 7BCT01	7BCT01	7BCT01 FU,RM		
69 7PAC01AP001	7PAC01AP001	7PAC01AP001 : FU,RM		
70 1LAC01AP001	1LAC01AP001	1LAC01AP001 : FU,RM		
71 4POS2c	4POS2	Okpos2		
72 1LBK01BC001 1	VD3-prac 1LBK01BC001 TVD3	LBK01BC001 TVD3 : PRAC, 1LBK TK1		
73 1LBK02BC001 1		LBK02BC001 TVD2 : PRAC, 1LBK TK2		
74 1LBK02BC001 1	VD3-prac 1LBK02BC001 TVD3	LBK02BC001 TVD3 : PRAC, 1LBK TK2		
75 1LCM12AP001-z	ap 1LCM12AP001	CM12AP001 : ZAP, 1LBKLCM2		
76 1JNF21AA003	1JNF21AA003	1JNF21AA003 : FU,RM		
77 1JNF21AP001	1JNF21AP001	1JNF21AP001 : FU,RM		
78 1JNF41AA003	1JNF41AA003	1JNF41AA003 : FU,RM		
79 1JNF41AP001	1JNF41AP001	1JNF41AP001 : FU,RM		
80 1JNF61AA003	1JNF61AA003	1JNF61AA003 : FU,RM		
		1.005.03		
Add activity		1.00E-03		ſъ
Add activity Calculate		1.00E-03 2.50E-04		
Calculate		2.50E-04		
Calculate		2 50E-04 2 00E-05 2 83E-06		
Calculate		2.50E-04		
Calculate		2 50E-04 2 00E-05 2 83E-06	C LERF C BOILING	04/23/2014 C TRIP



"RiskSpectrum RiskWatcher"

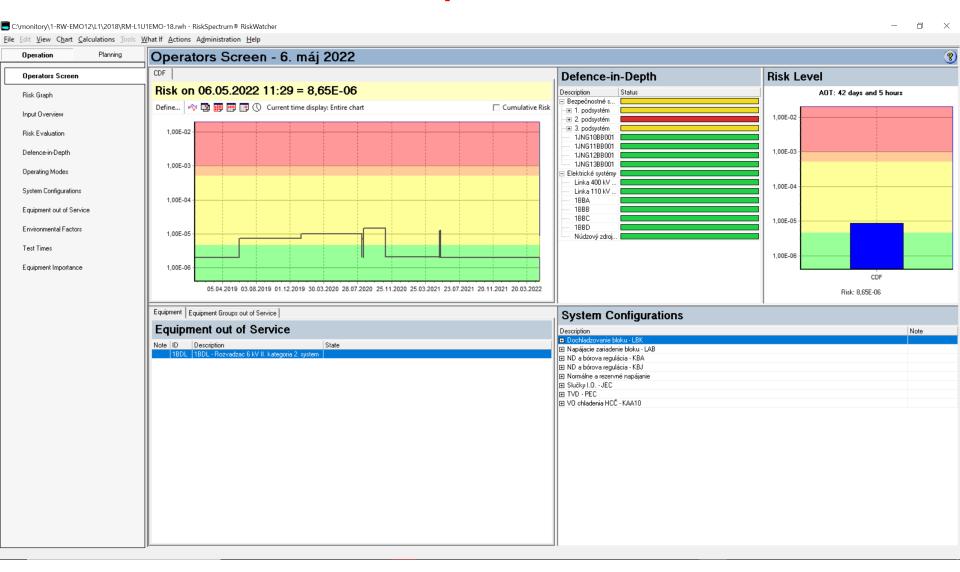
Two platforms:

>desktop version

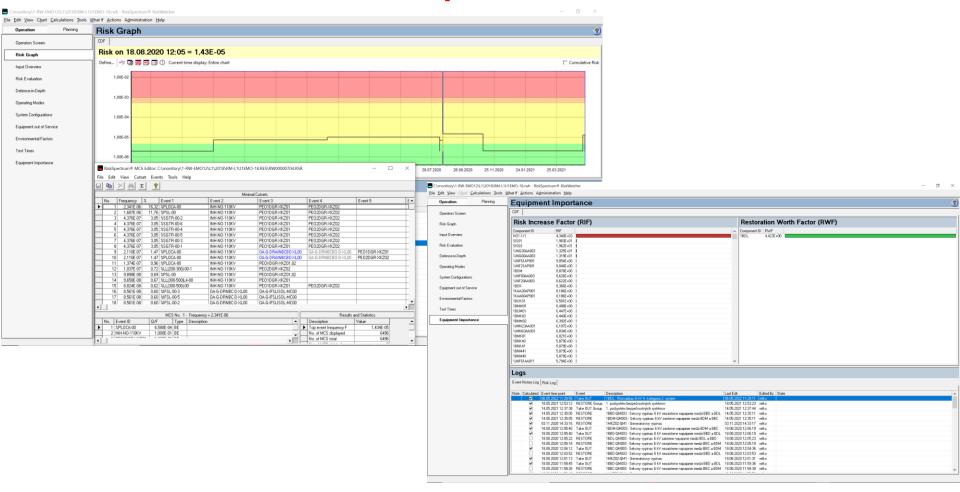
WEB version



Operation

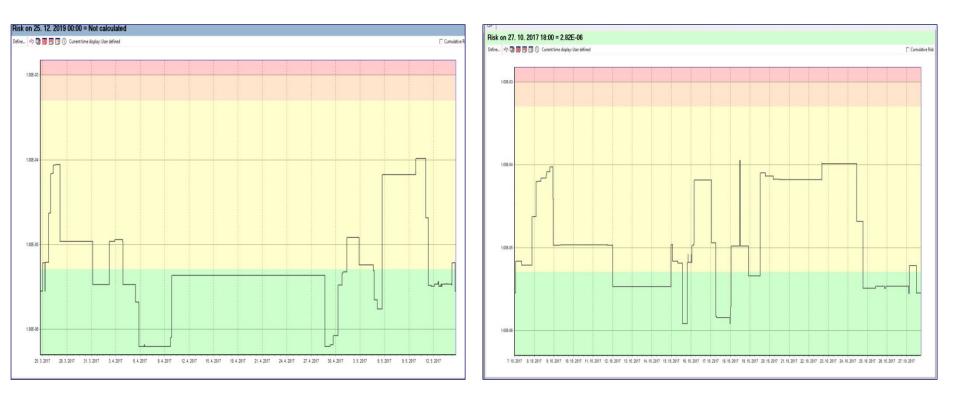


Operation



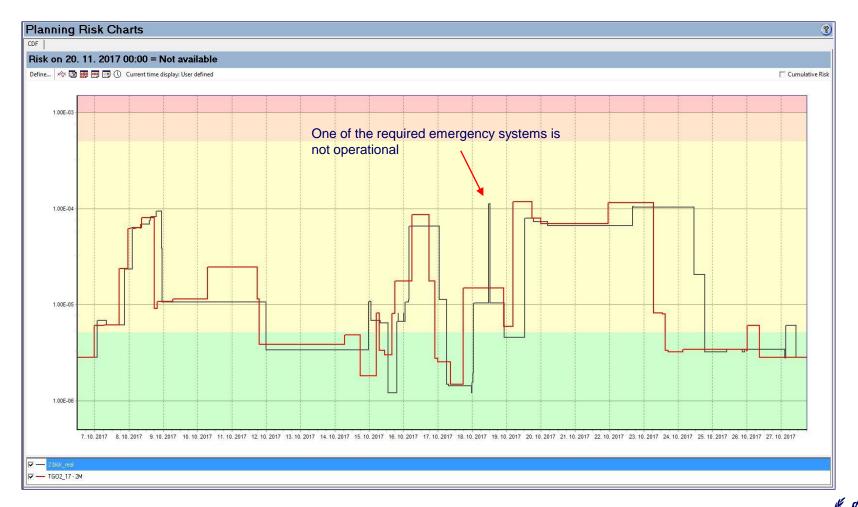


Planning





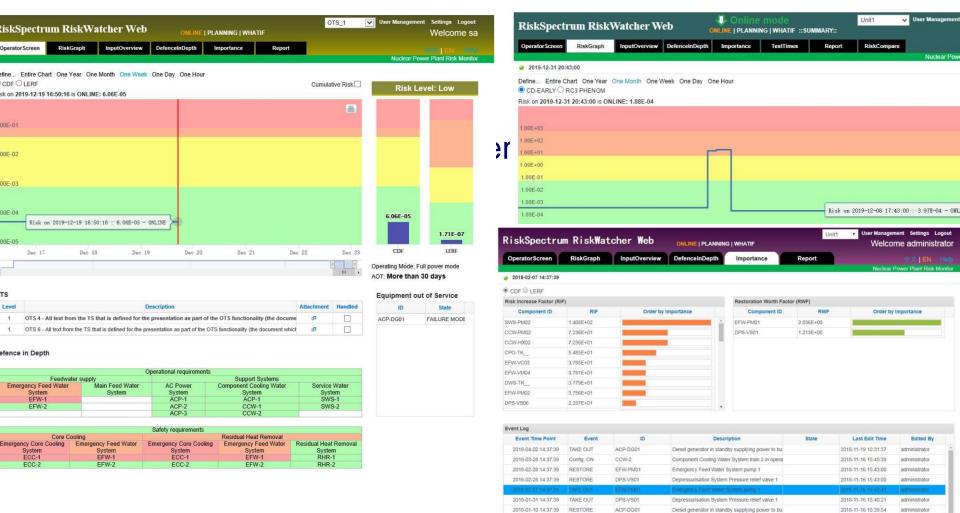
Planning





"RiskSpectrum RiskWatcher" - WEB

Online



2018-01-04 14:37:39

2018-01-01 14:37:39

PØ

TAKE OUT

EF ON

ACP-DG01

WINTER

Diesel generator in standby supplying power to bu

Winter conditions (November - April)

administrato

View 1 - 12 of 12

SYSTEM

2018-11-16 15:38:00

"RiskSpectrum RiskWatcher" - WEB

Online



Note	Event Time Point	Event	ID	Description	State	Last Edit Time	Edited By
	2019-12-31 20:43:00	RESTORE	ECC-VC02	Emergency Gore Cooling System check valve \$		2020-06-18 15 37:52	58
	2019-12-24 13:13:00	Config. ON	SWS-1	Service Water System train 1 in operation (2 sta		2020-06-18 15:37:52	sa
	2019-12-21 19:40:00	TAKE OUT	ACP-GT01	Gas Turbine in standby supplying power to bus		2020-06-18 15:37:52	sa
	2019-12-15 10:57:00	Config. OFF	MFWP1	Main Feed Water System P1 in operation		2020-06-18 15:37:52	sa
	2019-12-15 00:42:00	RESTORE	RHR-PM02	Residual Heat Removal System pump 1		2020-06-18 15:37:52	sa
	2019-12-08 17:43:00	TAKE OUT	RHR-PM01	Residual Heat Removal System pump 1		2020-06-18 15:37:52	sa
	2019-11-29 19:26:00	TAKE OUT	RHR-PM02	Residual Heat Removal System pump 1		2020-06-18 15:37:52	sa
	2019-11-23 14:50:00	Op. Mode ON	SHUT_DOWN	Shut down mode		2020-06-18 15:37:52	sa
	2019-11-22 17:19:00	TAKE OUT	ECC-VC02	Emergency Core Cooling System check valve 2		2020-06-18 15:37:52	sa
	2019-11-22 04:48:00	RESTORE	ACP-DG01	Diesel generator in standby supplying power to		2020-06-18 15:37:52	sa

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

ONLINE | PLANNING | WHATIF

Importance

Restoration Worth Factor (RWF)

Component ID

EFW-PM01

DPS-VS01

DefenceInDepth



Viser Management Settings Logout

Order by Importance

Welcome administrator

Nuclear Power Plant Risk Monito

Unit1

Report

RWF

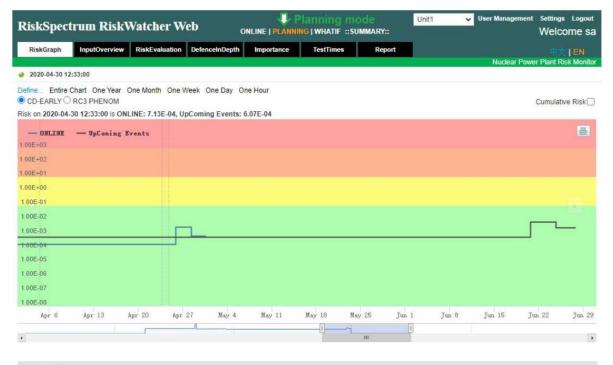
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1.213E+00

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"RiskSpectrum RiskWatcher" - WEB

Planning



Name	Description	Start Time	Owner	Share To	Create Date	Is Published
ONLINE	Operation event history log	2019-06-01 09:00:00	sa		2020-06-18 15:23:34	YES
UpComing Ev	UpComing Events	2019-06-01 09:00:00	sa		2020-06-18 15:23:34	NO
plan1		2020-06-19 00:00:00	sa		2020-06-18 16:15:50	NO

63

Event Log | Risk Log

Event	Log - ON	LINE							
	Note	Event Time Point	Event	ID	Description	State	Last Edit Time	Edited By	6
		2020-04-30 12:33:00	Test	CCW/2	Test of Component Cooling Water System train		2020-06-18 16:18:04	-	gy Agency 🕻
		2020-04-28 07:56:00	RESTORE	ACP-DG02	Diesel generator in standby supplying power to		2020-06-18 16:18:04	sa	gy rigonoy
\Box		2020-04-27 15:26:00	TAKE OUT	DPS-VS01	Depressurisation System Pressure relief valve		2020-06-18 16:18:04	sa	

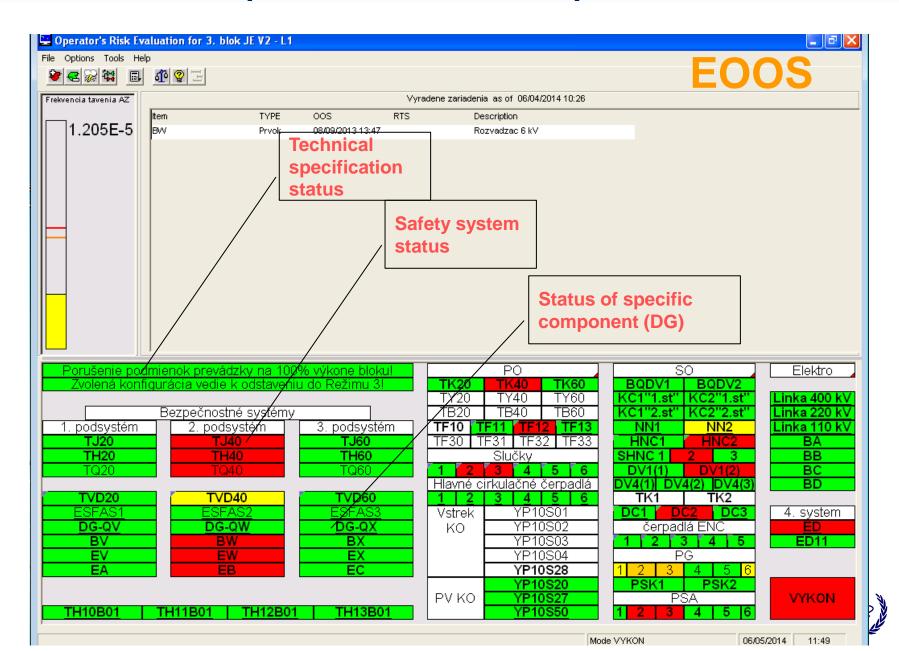
Defence-in-Depth structures – qualitative part of Risk monitors

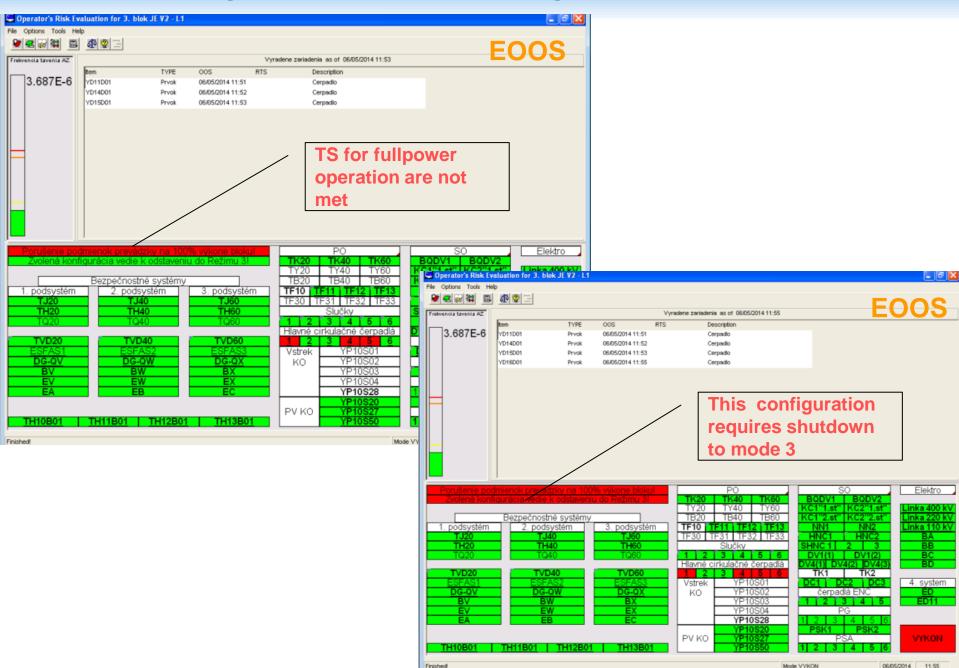
- Provide qualitative risk assessment
- Provide instantaneous (visual) information about the availability of systems, subsystems and components, safety functions.
- > Illustrate relations and dependencies between systems, etc.

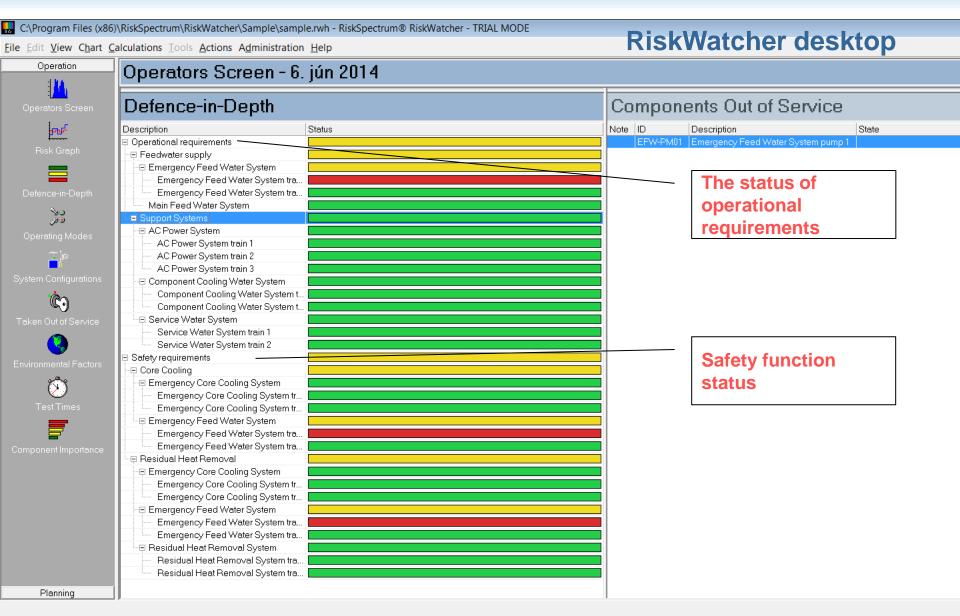
Examples of Ways to Use DiD Danal Displays

	JI Ways to Use		J Panel Displays
Item Monitored		١	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	Red	=	Plant is not in compliance
specifications	Yellow/Orange	=	Plant is partially in compliance
	Green	=	Plant is in compliance









RiskSp	ectrum RiskWa	atcher Web	ONLIN	IE PLANNING WHATIF	OTS_1	User Management S V	Settings Logo Welcome s	
Operator Sc	creen RiskGraph	InputOverview	DefenceInDepth	Importance Re	Report			190
2019-09-0	05 47:03:39					Nuclear Power F	Plant Risk Mon	itor
 Vacation 	Depth Defence in Depth Ov	ver Time			RiskWatc	her WF	ΞB	
Defence in	n Depth [Hide OTS]							
				Operational requirements				
-		ater supply			Support Systems			
Emerge	gency Feed Water System EFW-1	Main Feed	d Water System	AC Power System	Component Cooling Water System ACP-1		Water System SWS-1	
	EFW-1 EFW-2			ACP-1 ACP-2	CCW-1		SWS-1	The status of
	LT IT 2			ACP-3	CCW-2		102	operational
P				Safety requirements				requirements
line -	Core Co	ooling		Salety requirements	Residual Heat Removal			
Emergence	cy Core Cooling System ECC-1	Emergency Feed Wa EFW-1		Emergency Core Cooling System ECC-1		Residual Heat Re		<u> </u>
-	ECC-2	EFW-2		ECC-2	EFW-2	RHR		
OTS							<u> </u>	The status of Safety
			Ţ	Description		Attachment	a second second second	
Level								- Equilementa Jaret
Level 1	OTS 4 - All text from the	TS that is defined for t	the presentation as	s part of the OTS functionality (the second se	the document which is referred to from V	the gat 🖉		svstems

Note	Event Time Point	Event	ID	Description St	ate 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 N	ODE 1 2019-12-16 15:15:26	58
	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



Example 1

🚰 Safety Monitor 4.2: Administrator ((Administrator) - [Schedule case - case0]					
<u>Case Insert Sort Tools Options View H</u>	Help					
Plant Unicode Demo Unit 1 💌 Operatio	ion Schedule mode 🛛 🔽 Graph 7 days 🔽 Debug DFF 💌 Searc	h			Eve	nt values unchanged Calculate
	Jun 2009					^
# Activity Activity item			5		7	
1 01-CW-P -1D - 1-CW-P-1D	1-CW-P-1D : FU,RM					
2 01-EE-EG -1J - 1-EE-EG-1J	1-EE-EG-1J : FU,RM (Shared: 2)					
3 01-CC-CKT-1CCPB1-CC-P-1B	1-CC-P-1B : FU,RM (Shared: 2)				Cofoty Mo	
4 01-CC-E -1B -+1-CC-E-1B	1-CC-E-1B : FU,RM (Shared: 2)				Safety Mo	nitor
5 01-CC-P -1B -F1-CC-P-1B	1-CC-P-1B : FU,RM (Shared: 2) 1-CC-TV-101B : FU,RM					
6 01-CC-TV -101B 1-CC-TV-101B 7 01-SA-C -1 -M1-SA-C-1	1-SA-C-1 : FU,RM (Shared: 2)					
8 01-SW-P -4 -F1-SW-P-4	1-5W-P-4 : FU.RM (Shared: 2)					
9 02-CH-P -1C1 - 2-CH-P-1C	2-CH-P-1C : FU.RM (Shared: 2)					
10 01-QS-P -1B -F1-QS-P-1B	1-QS-P-1B;; F	U,RM				
11 ABENV Abnormal Env	Abnormal Em	/ (Shared: 2)				
12 FTEVOL FIRST_EVOL	FIRST_EVOL					
13 01-CH-P -1C1 -1-CH-P-1C		: FU,RM (Shared: 2)				
14 01-CH469 -√1-CH-P-1C		FU,RM (Shared: 2)				
15 01-CH279 -√1-CH-P-1C 16 01-CH-P -2C -F1-CH-P-2C	1-CH-P-1C 1-CH-P-2C	: FU,RM (Shared: 2)				
17 01-CH279 -VHi-Contam	Hi-Contam					
18 01-RS-E -2B -+1-RS-P-2B		1-RS-P-2B ; FU.RM				
19 01-RS-P -1B -F1-RS-P-1B		1-RS-P-1B : FU,RM				
20 01-RS-P -2B -F1-RS-P-2B		1-RS-P-28 ; FU,RM				
21 01-RS -P -3B -F 1-RS-P-3B		1-RS-P-3B ; FU,RM				
22 01-RH-E -1B -I1-RH-E-1B		1-RH-E-1B : FU,RM				
23 01-RH-P -1B -I1-RH-P-1B		1-RH-P-1B : FU,RM				
24 RWP RWP		RWP (Shared: 2)				~
PRA RISK						<u>^</u>
ELECTRICAL AC						
PRIMARY IMVENTORY PRIMARY/SECONDARY HEAT SINK						
ULTIMATE HEAT SINK						
INDUSTRIAL SAFETY						
RADIOLOGICAL SAFETY						
Schedule mode : Unit 1		4	ls ' _ '		7	
Safety functions	4 p	4		•	<i>ү</i> •	۹ ۱
						>
Risk profile Safety functions - All Safety funct	tions - Online Safety functions - Outage					
Saley functions - All Carety function						
Safety Monitor For Help, Press F1						Monday February 07 2011 04:53 PM
						•

Critical Safety Function Status display in Schedule Mode



- 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.



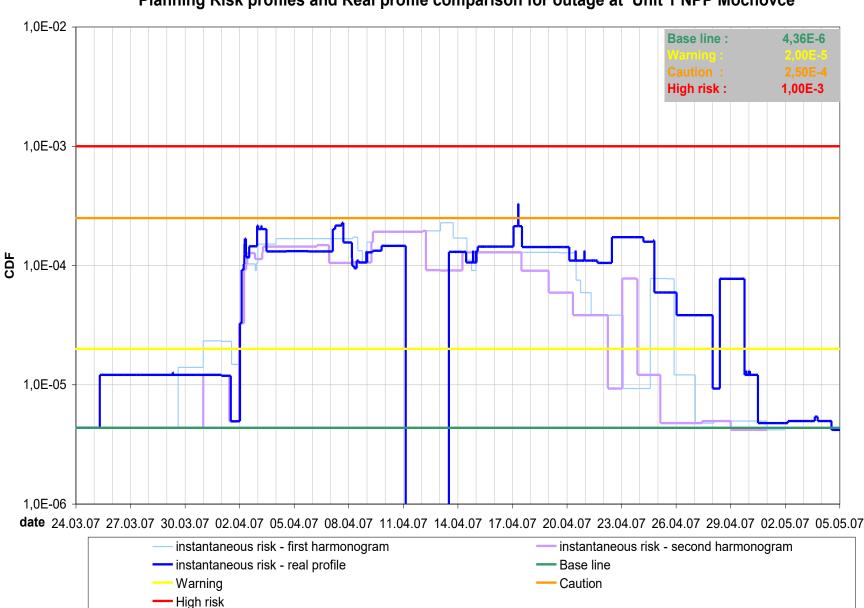
An example of specific steps of the refuelling outage analysis using Risk monitor software:

- 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
- daily risk profile evaluation during the refuelling outage + final real risk profile for whole refuelling outage



Preliminary refuelling outage schedule

	SYSTEM KALENDAR		4				4	E							1 4	2	12 14	AP 15		17	40	10	00	04	00		2 0		5 0)7	20	20	20	4	MA
	P. C. DNA ODS IAVKY	0	1	2	3		4	5	6	-	8	9	1	0 1 0 1	1 1 1 1	2	13 14 13 14	15 15	16 16	17 17	18 18		20	21	22	2	3 22 3 22		5 2	26 2	27	28 28	29 29	30		
	Režimy bloku:			R5F	6																	R5					TS 12	2 25				1	rG11			
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j	Slučka č.1:					830		/) el m					0%1					OINS	N RE														
	Slučka č.2:						F	FX)	HCA.	, n.	<u>2 ei. m</u>		HCA	- I																						
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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.



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