Risk-Informed Regulation and Applications in Taiwan

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Outline

I、Introduction

II、Development of the Risk Engine

III、Development of Risk Monitor

IV、Development of the SDP Tool, PRiSE

V、Development of Risk-Informed Fire Analysis and ISI

VI、Conclusions

I、Introduction (1 of 4)

- The Probabilistic Risk Assessment (PRA) group of INER has developed and maintains the PRA models of all the nuclear power plants (NPPs) for Taiwan Power Company (TPC) over 20 years since PRA was first introduced to Taiwan's NPPs
- These PRA models cover internal and external events, power operation and shutdown mode, with LERF (Large Early Release Frequency) calculation modules
- The PRA group has also completed a dedicated risk monitor with indigenous model solver engines, which are now adopted by the domestic three NPPs to monitor daily operation risks

I、Introduction (2 of 4)

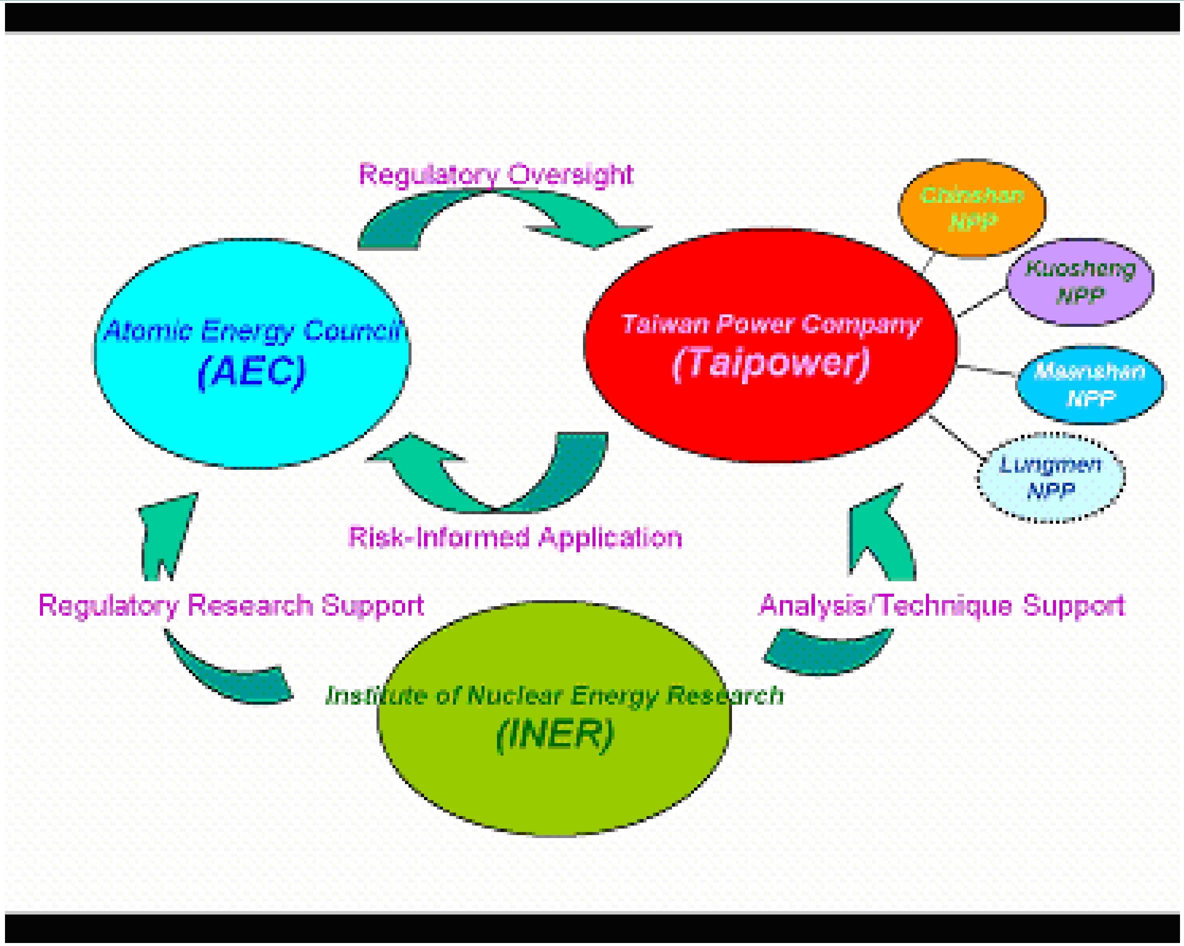
- The second generation of the risk monitor, TIRM-2 (Taipower Integrated Risk Monitor-2) with calculation capabilities of LERF has been developed successfully in Taiwan
- A window-based tool with the Significance Determination Process (SDP) context to help the resident inspectors of Taiwan's nuclear regulatory body to perform the Phase 2 SDP assessment of the Reactor Oversight Process (ROP) has also been completed
- Recently, the approval of on-line maintenance of Residual Heat Removal (RHR) systems and acceptance of PRA peer review reports on all of the three Taiwan's operating NPPs have created a basis of risk-informed applications in Taiwan

I、Introduction (3 of 4)

- Since 2003, the Minister of Taiwan’s Atomic Energy Council, Dr. Min-Shen Ouyang has been reiterating that AEC’s overall goals in regulating Taipower’s six operating LWRs are threefold: “Safety First, Deregulation, and Administrative Simplification.”

- The second and third points are new policy, and are an indication that things are moving in a positive direction. Taiwan’s regulatory body is working with Taipower management to “gradually introduce” risk-informed practices into Taiwan

I、Introduction (4 of 4)



"The Nuclear Triangle" in Taiwan

II、Development of the Risk Engine (1 of 2)

- The development of Taiwan's risk engine has paved a successful path for providing the helpful tools for Risk-Informed Regulation/Applications
- On the need of both AEC and Taipower, INER has successfully developed an integrated PRA module for various fields of applications
- The module includes a super risk engine, the INERISKEN (INER Risk Engine) to solve PRA model within one minute, an advanced PRA model (or usually defined as risk model in risk monitor) in the form of top-logic fault tree

II、Development of the Risk Engine (2 of 2)

- The results showed that INERISKEN has excellent performance and can be used in any applications
- INERFT (INER Fault Tree) is purely a fault tree engine developed to quickly solve a fault tree. It is a 32-bit application written in ANSI C language under PC Windows's operating system
- In addition to the nuclear industry, INERFT is also applied to other non-nuclear industry in Taiwan

III、Development of Risk Monitor (1 of 6)

- On the basis of the accomplished living PRA models on all of the three Taiwan's NPPs, INER and TPC have collaboratively developed a risk monitor, the Taipower Integrated Risk Monitor (TIRM), for each NPP
- Due to the TIRM's robust function and its successful development, since June of 2001, Taiwan's nuclear regulatory body has requested that each NPP evaluate shutdown risk before TPC performs refuelling outages and calculate the associated risk profile daily by the TIRM

III、Development of Risk Monitor (2 of 6)

- For further risk-informed applications, only Core Damage Frequency (CDF) index in the TIRM is not sufficient
- A new risk engine, the INERISKEN, developed by INER was incorporated into the TIRM-2
- By introducing the new powerful risk model solver INERISKEN, the TIRM-2 is designed to have more capabilities and to run faster than TIRM does

III、Development of Risk Monitor (3 of 6)

- The TIRM–2 on power and on refuelling outages has been released to all of the three operating NPPs for their usage
- With the capability of performing CDF and LERF calculations, the TIRM-2 becomes a very helpful tool in monitoring the risk of different plant states and provides further information directly for risk-informed applications

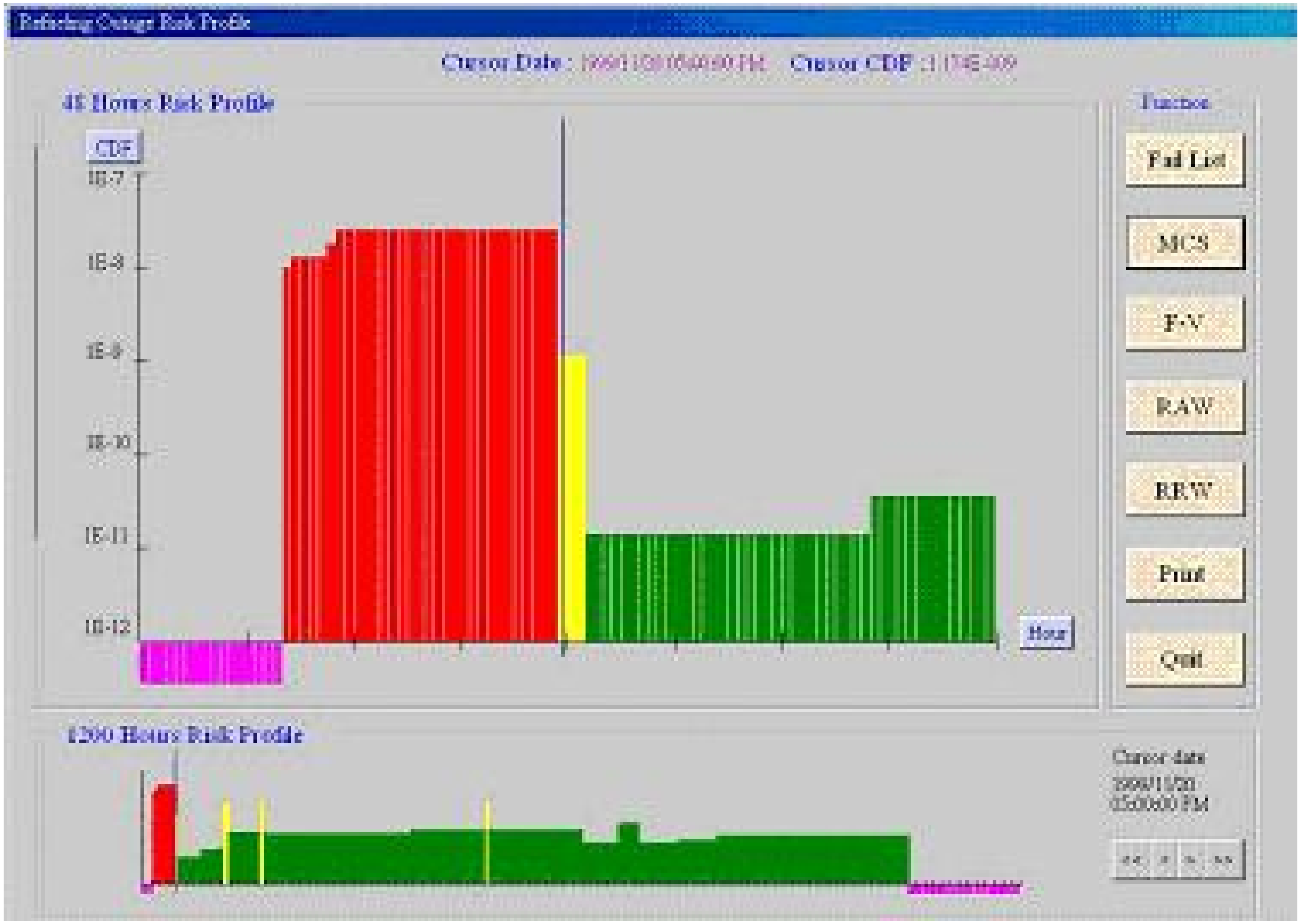
III、Development of Risk Monitor (4 of 6)

- TIRM-2 can be used to track CDF, LERF, ΔCDF, and ΔLERF during power operations, on-line maintenance, and refuelling outages
- TIRM-2 can provide useful information regarding the status of safety systems, the risk profile over the last 24 hours, and the usual importance measures

III、Development of Risk Monitor (5 of 6)

Risk Profiles with CDF and LERF at Power Operation in TIRM-2

III、Development of Risk Monitor (6 of 6)



Risk Profiles during Refueling Outage in TIRM-2

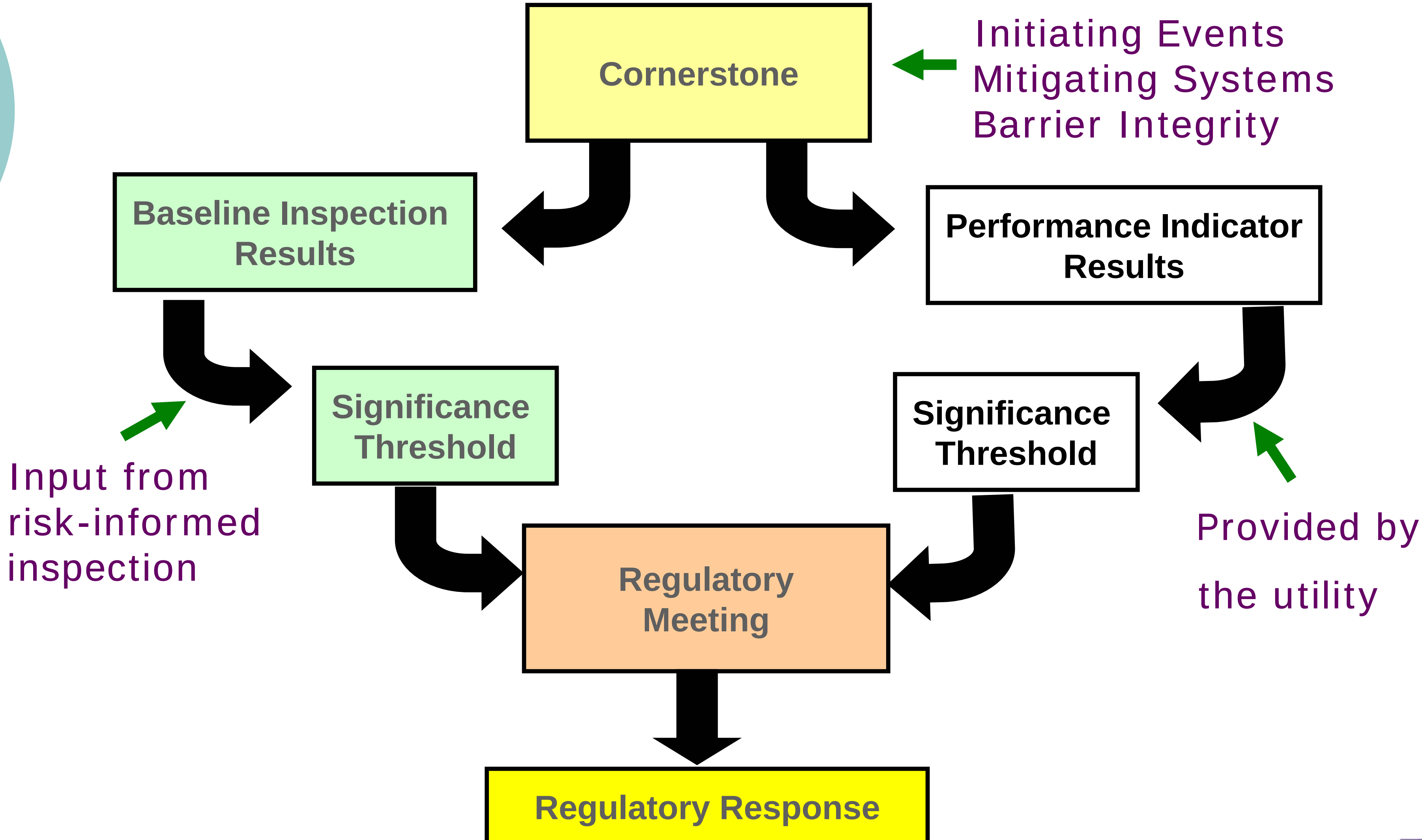
IV、Development of the SDP Tool, PRiSE (1 of 13)

- **P**RA Model Based **Ri**sk **S**ignificance **E**valuation
- A computer tool to evaluate risk significance of inspection findings under the request from AEC
- Risk significance is determined by ΔCDF and indicated by four different color codes (GWYR)
- Risk-informed and efficient process to evaluate inspection findings
- Provide bases of decision making for inspectors

IV、Development of the SDP Tool, PRiSE (2 of 13)

- Taiwan AEC decides to adopt a new approach, so called "Green/Red Lights" scheme, for nuclear safety oversight starting from January of year 2006
- The "Green/Red Lights"-scheme approach is inspired from the revised Reactor Oversight Process (ROP) of the USNRC
- Under this scheme, the performance indicators are provided by the utility and inspection findings of the resident inspectors provide the inputs to the regulatory action considerations

IV、Development of the SDP Tool, PRiSE (3 of 13)



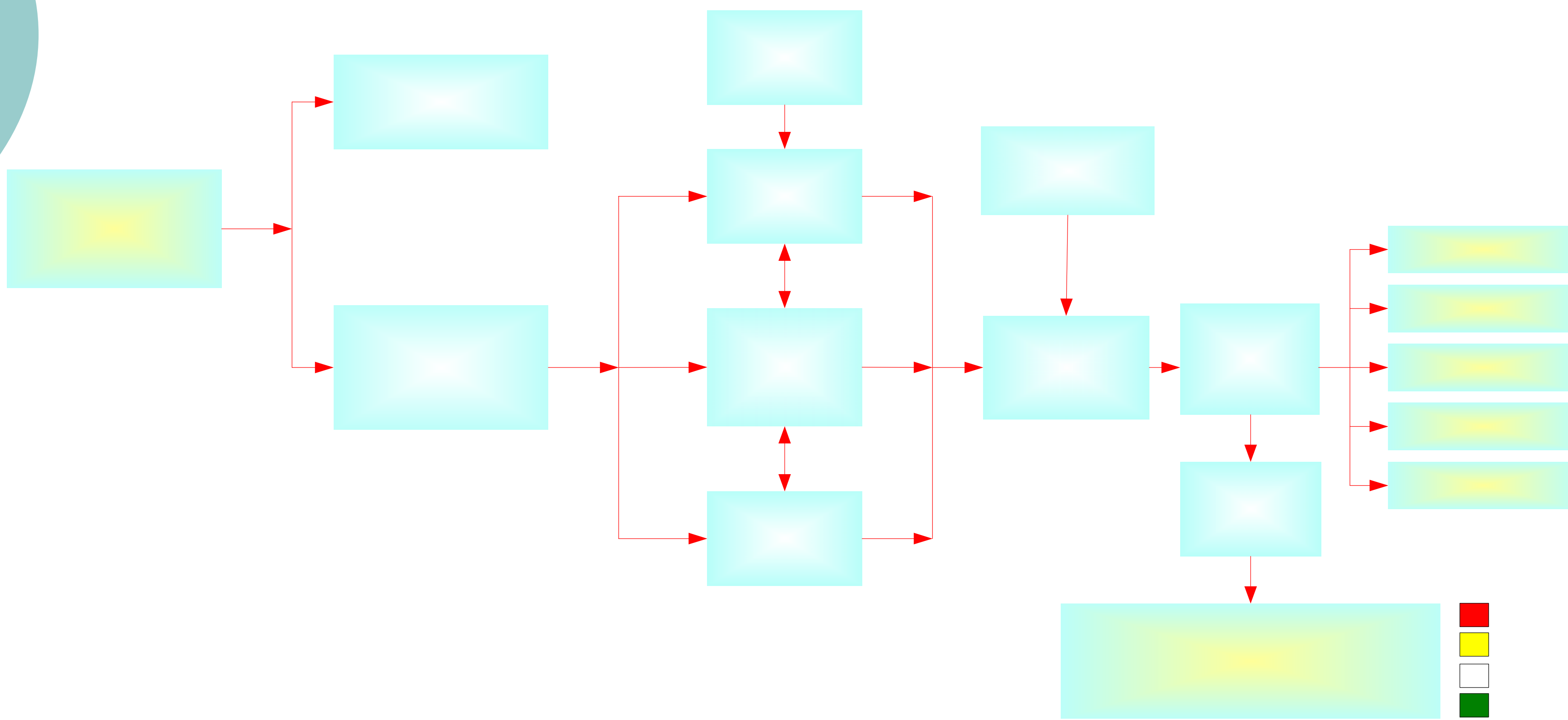
IV、Development of the SDP Tool, PRiSE (4 of 13)

- Tabled SDP developed by the USNRC (IMC 0609)
- For internal events of power operation (App. A)
  - Phase 1: screen out insignificant findings (Inspector)
  - Phase 2: determine risk significance (Inspector)
  - Phase 3: more rigorous assessment (SRA)
- Perform phase 1, 2 and part of phase 3 SDP assessment
- Provide process to screen out insignificant finding

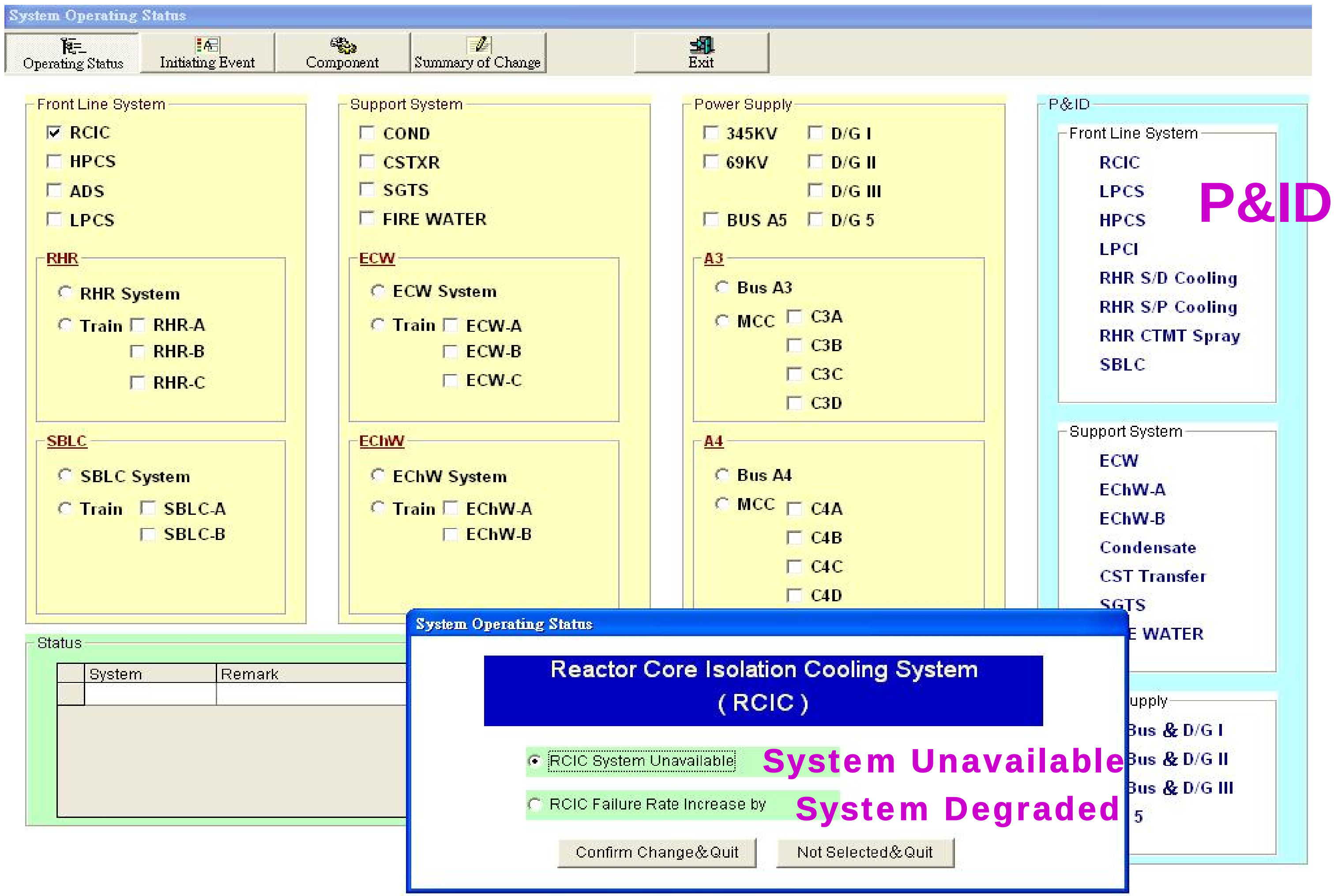
IV、Development of the SDP Tool, PRiSE (5 of 13)

- Obtain ΔCDF by resolving living PRA model
- Allow inspectors to define plant deficiencies by
  - Safety systems/components are unavailable or degraded
  - Change of initiating event frequencies
- Simplified P&IDs to indicate SSCs modeled in PRA
- Provide guidance for IE frequency changes
- Use four different color codes to define risk significance
- Provide additional risk information
  - MCSs and important measures (F-V, RAW, RRW)

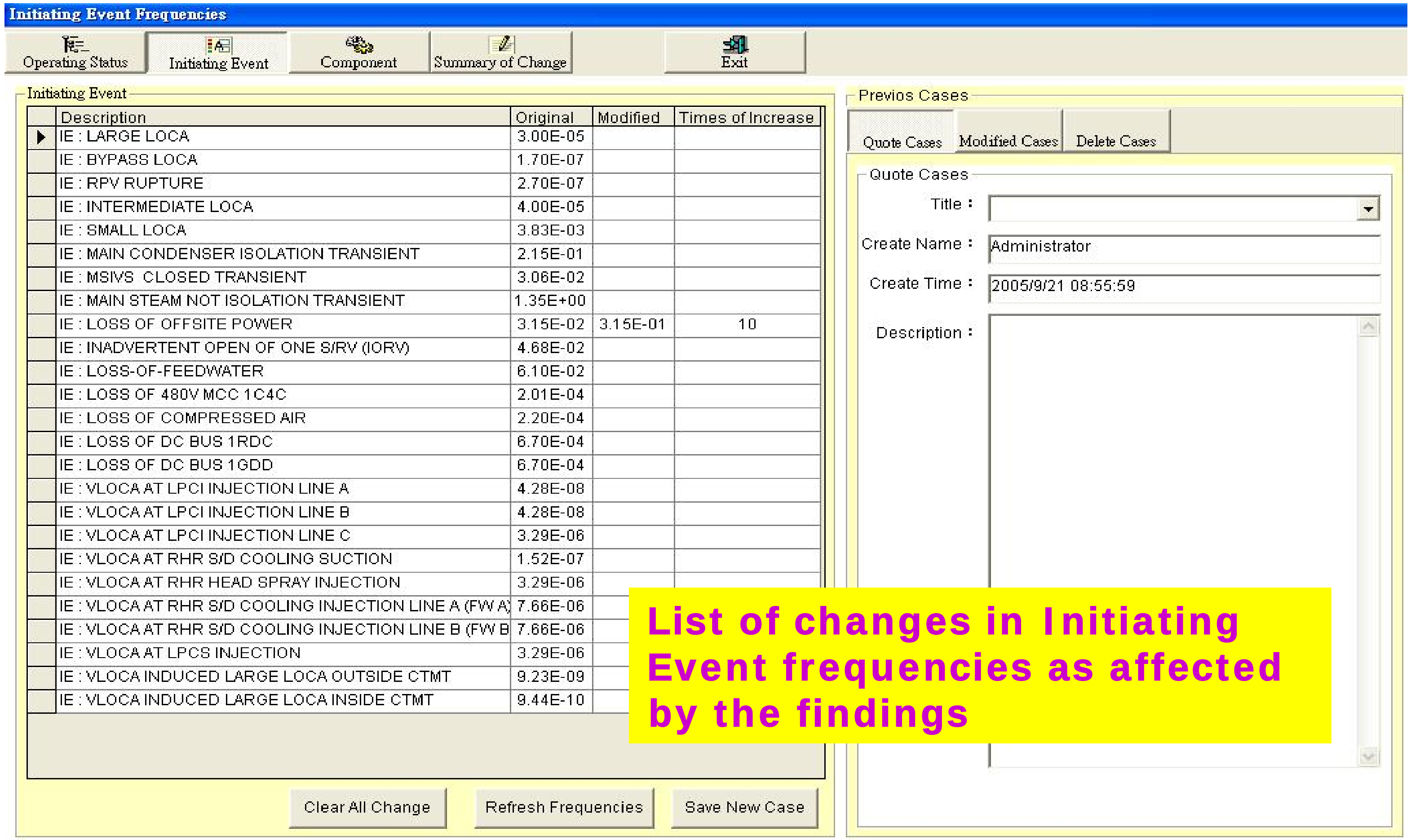
IV、Development of the SDP Tool, PRiSE (6 of 13)



IV、Development of the SDP Tool, PRiSE (7 of 13) Safety-Related System List



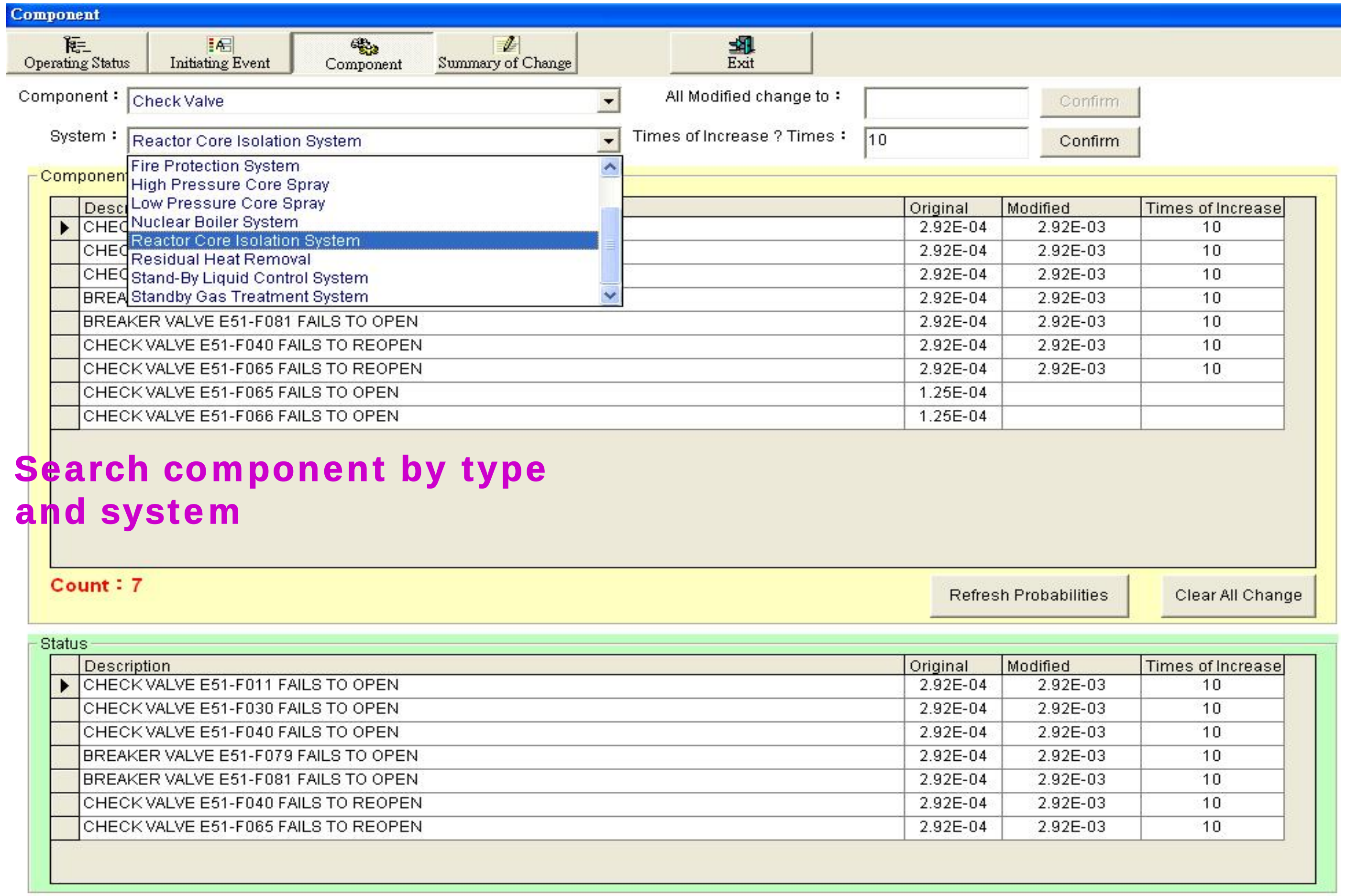
IV、Development of the SDP Tool, PRiSE (8 of 13)



Description	Original	Modified	Times of Increase
IE : LARGE LOCA	3.00E-05		
IE : BYPASS LOCA	1.70E-07		
IE : RPV RUPTURE	2.70E-07		
IE : INTERMEDIATE LOCA	4.00E-05		
IE : SMALL LOCA	3.83E-03		
IE : MAIN CONDENSER ISOLATION TRANSIENT	2.15E-01		
IE : MSIVS CLOSED TRANSIENT	3.06E-02		
IE : MAIN STEAM NOT ISOLATION TRANSIENT	1.35E+00		
IE : LOSS OF OFFSITE POWER	3.15E-02	3.15E-01	10
IE : INADVERTENT OPEN OF ONE S/RV (IORV)	4.68E-02		
IE : LOSS-OF-FEEDWATER	6.10E-02		
IE : LOSS OF 480V MCC 1C4C	2.01E-04		
IE : LOSS OF COMPRESSED AIR	2.20E-04		
IE : LOSS OF DC BUS 1RDC	6.70E-04		
IE : LOSS OF DC BUS 1GDD	6.70E-04		
IE : VLOCA AT LPCI INJECTION LINE A	4.28E-08		
IE : VLOCA AT LPCI INJECTION LINE B	4.28E-08		
IE : VLOCA AT LPCI INJECTION LINE C	3.29E-06		
IE : VLOCA AT RHR S/D COOLING SUCTION	1.52E-07		
IE : VLOCA AT RHR HEAD SPRAY INJECTION	3.29E-06		
IE : VLOCA AT RHR S/D COOLING INJECTION LINE A (FW A)	7.66E-06		
IE : VLOCA AT RHR S/D COOLING INJECTION LINE B (FW B	7.66E-06		
IE : VLOCA AT LPCS INJECTION	3.29E-06		
IE : VLOCA INDUCED LARGE LOCA OUTSIDE CTMT	9.23E-09		
IE : VLOCA INDUCED LARGE LOCA INSIDE CTMT	9.44E-10		

List of changes in Initiating Event frequencies as affected by the findings

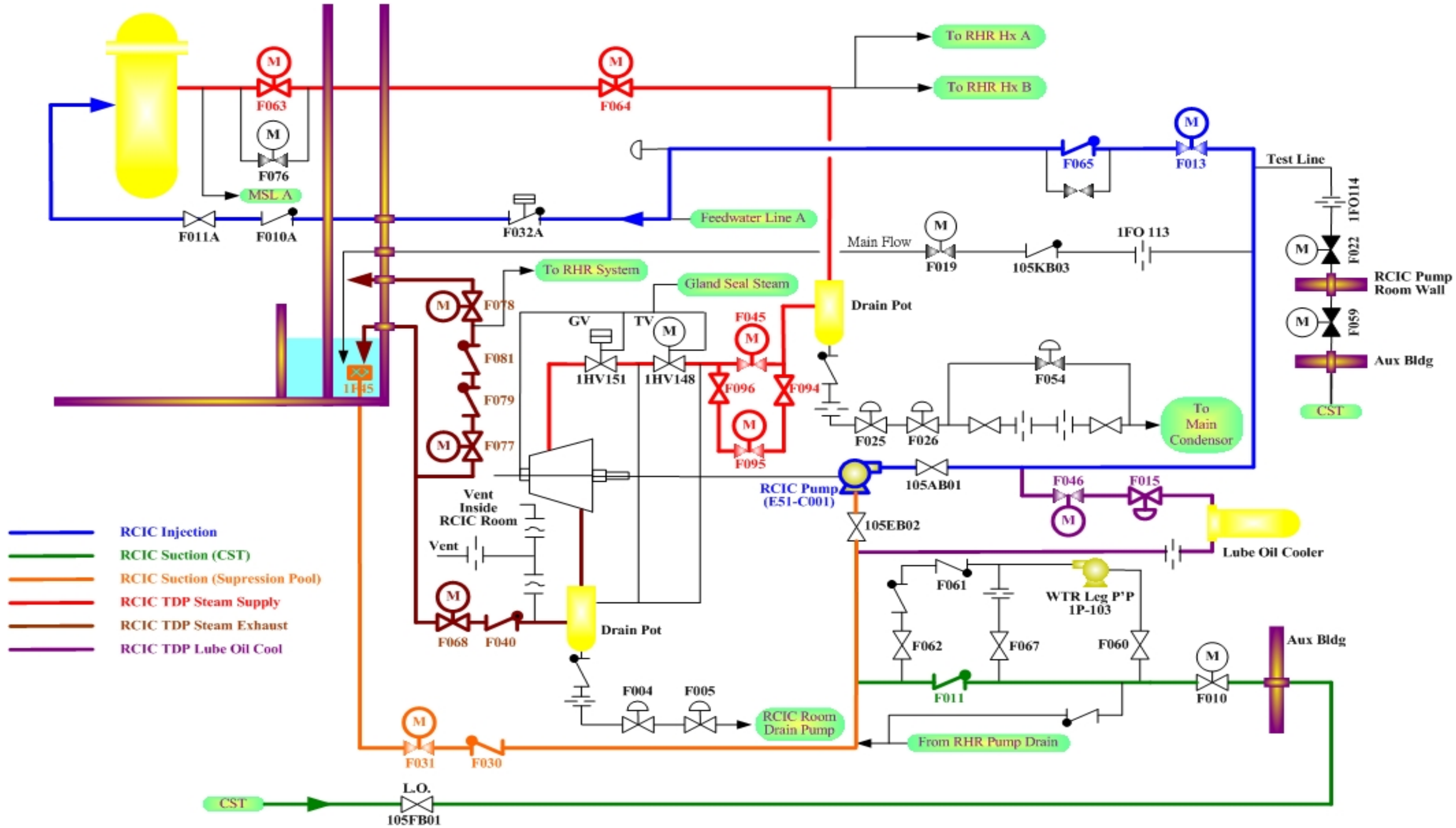
IV、Development of the SDP Tool, PRiSE (9 of 13)



Search component by type and system

IV、Development of the SDP Tool, PRiSE (10 of 13) Display of SSCs modeled in PRA

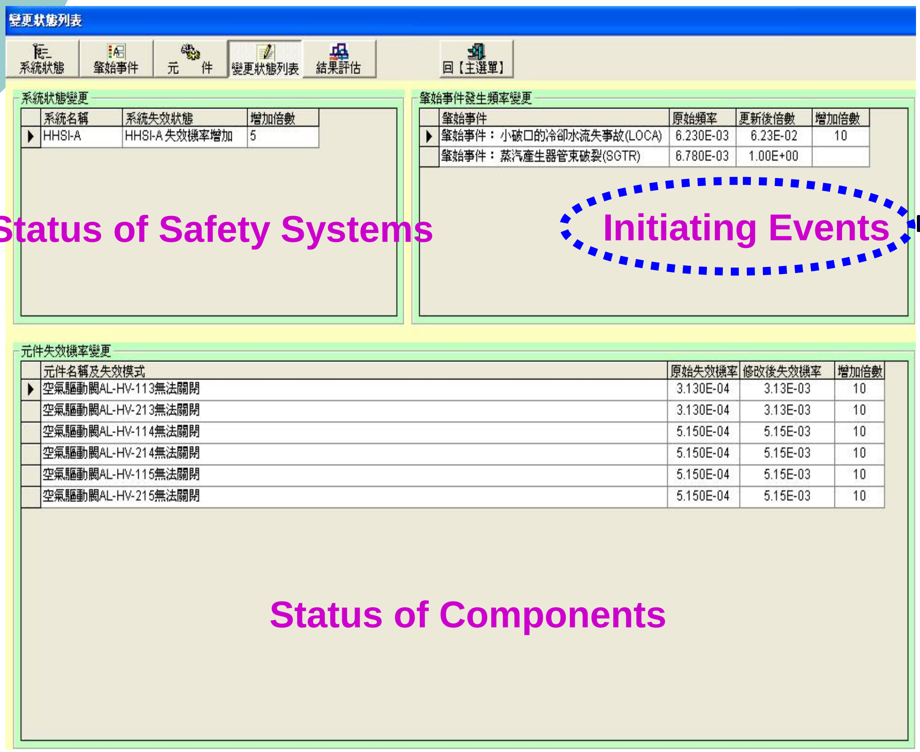
Component modeled in PRA shown in color



Reactor Core Isolation Cooling System (RCIC)

IV、Development of the SDP Tool, PRiSE (11 of 13)
Final List of Changes & IE change guidance (new feature)

IE affect by deficiency were shown in Red color



系統狀態變更

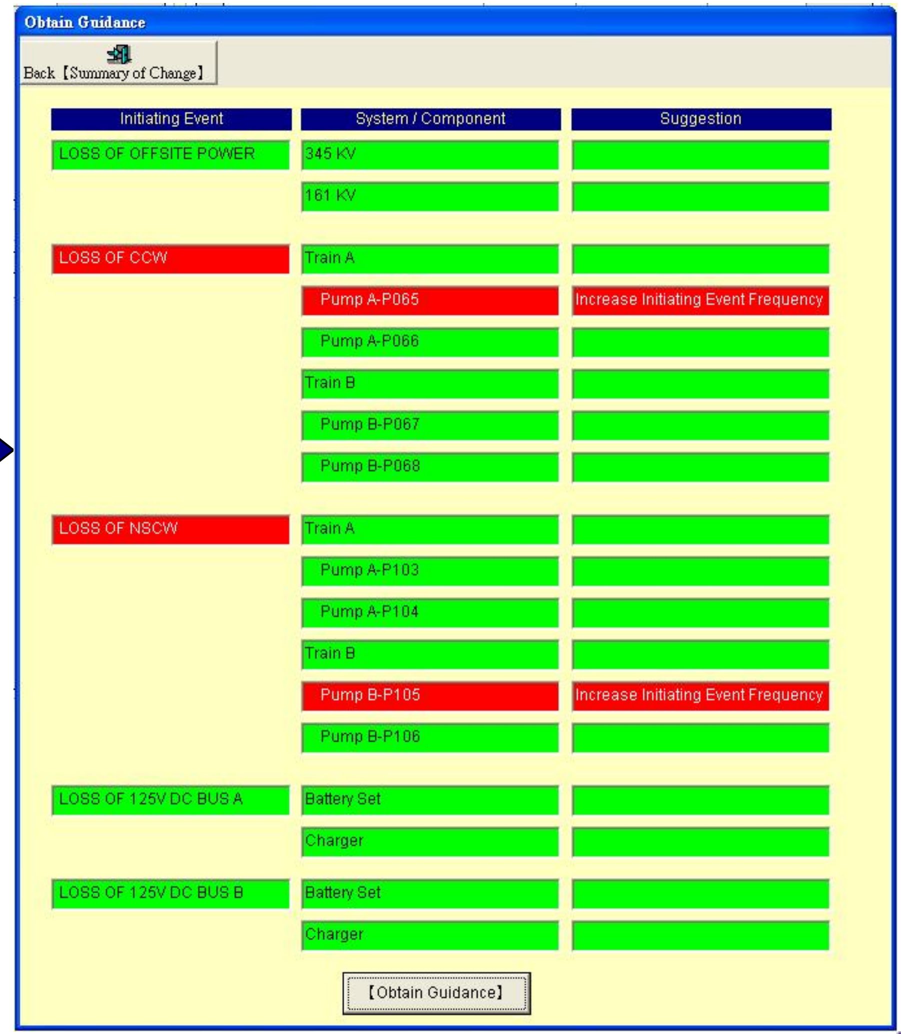
系統名稱	系統失效狀態	增加倍數
HHSI-A	HHSI-A 失效機率增加	5

肇始事件發生頻率變更

肇始事件	原始頻率	更新後倍數	增加倍數
肇始事件：小破口的冷卻水流失事故(LOCA)	6.230E-03	6.23E-02	10
肇始事件：蒸汽產生器管束破裂(SGTR)	6.780E-03	1.00E+00	

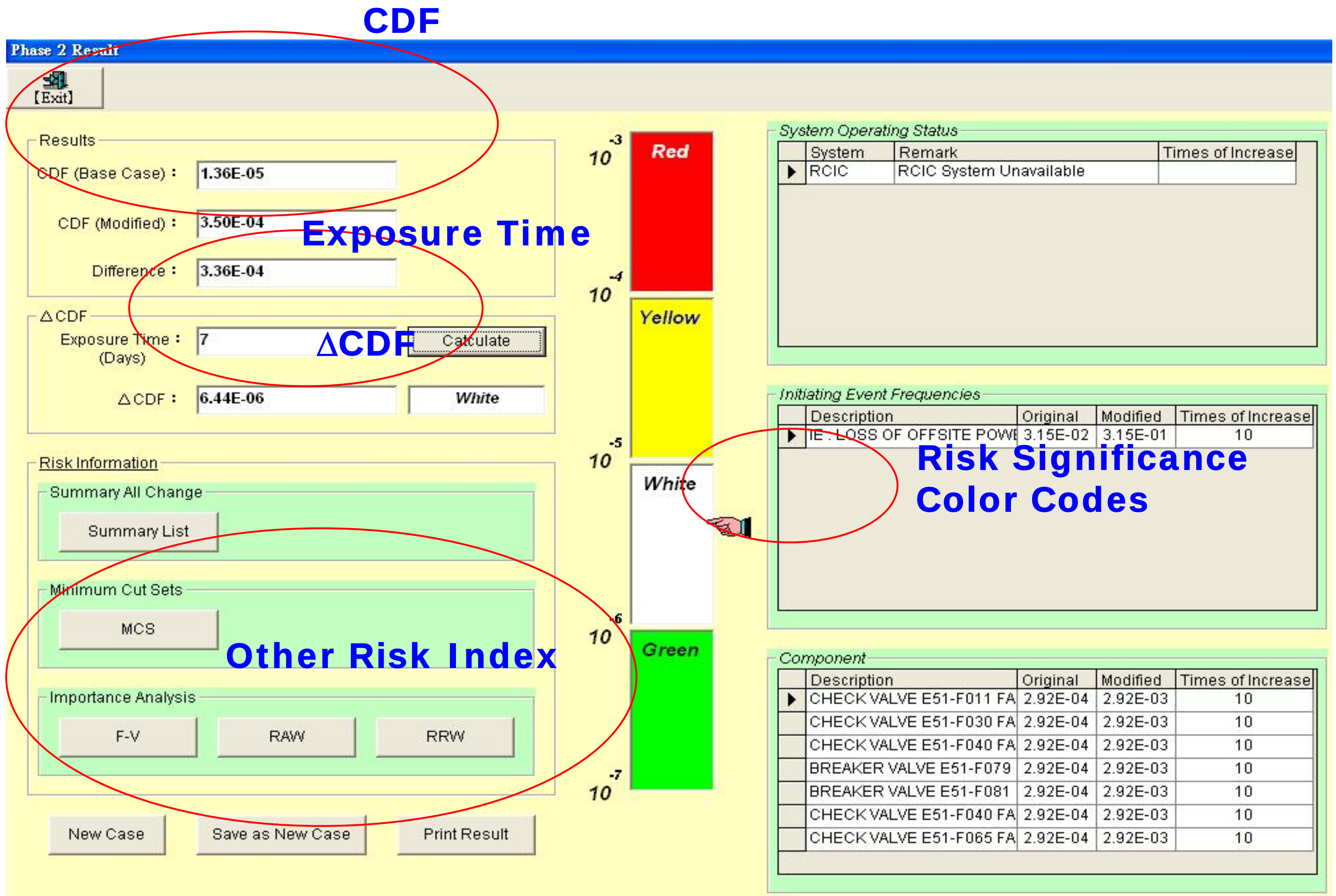
元件失效機率變更

元件名稱及失效模式	原始失效機率	修改後失效機率	增加倍數
空氣驅動閥AL-HV-113無法關閉	3.130E-04	3.13E-03	10
空氣驅動閥AL-HV-213無法關閉	3.130E-04	3.13E-03	10
空氣驅動閥AL-HV-114無法關閉	5.150E-04	5.15E-03	10
空氣驅動閥AL-HV-214無法關閉	5.150E-04	5.15E-03	10
空氣驅動閥AL-HV-115無法關閉	5.150E-04	5.15E-03	10
空氣驅動閥AL-HV-215無法關閉	5.150E-04	5.15E-03	10



Initiating Event	System / Component	Suggestion
LOSS OF OFFSITE POWER	345 KV	
	161 KV	
LOSS OF CCW	Train A	
	Pump A-P065	Increase Initiating Event Frequency
	Pump A-P066	
	Train B	
	Pump B-P067	
	Pump B-P068	
LOSS OF NSCW	Train A	
	Pump A-P103	
	Pump A-P104	
	Train B	
	Pump B-P105	Increase Initiating Event Frequency
	Pump B-P106	
LOSS OF 125V DC BUS A	Battery Set	
	Charger	
LOSS OF 125V DC BUS B	Battery Set	
	Charger	

IV、Development of the SDP Tool, PRiSE (12 of 13) Significance Determination Results



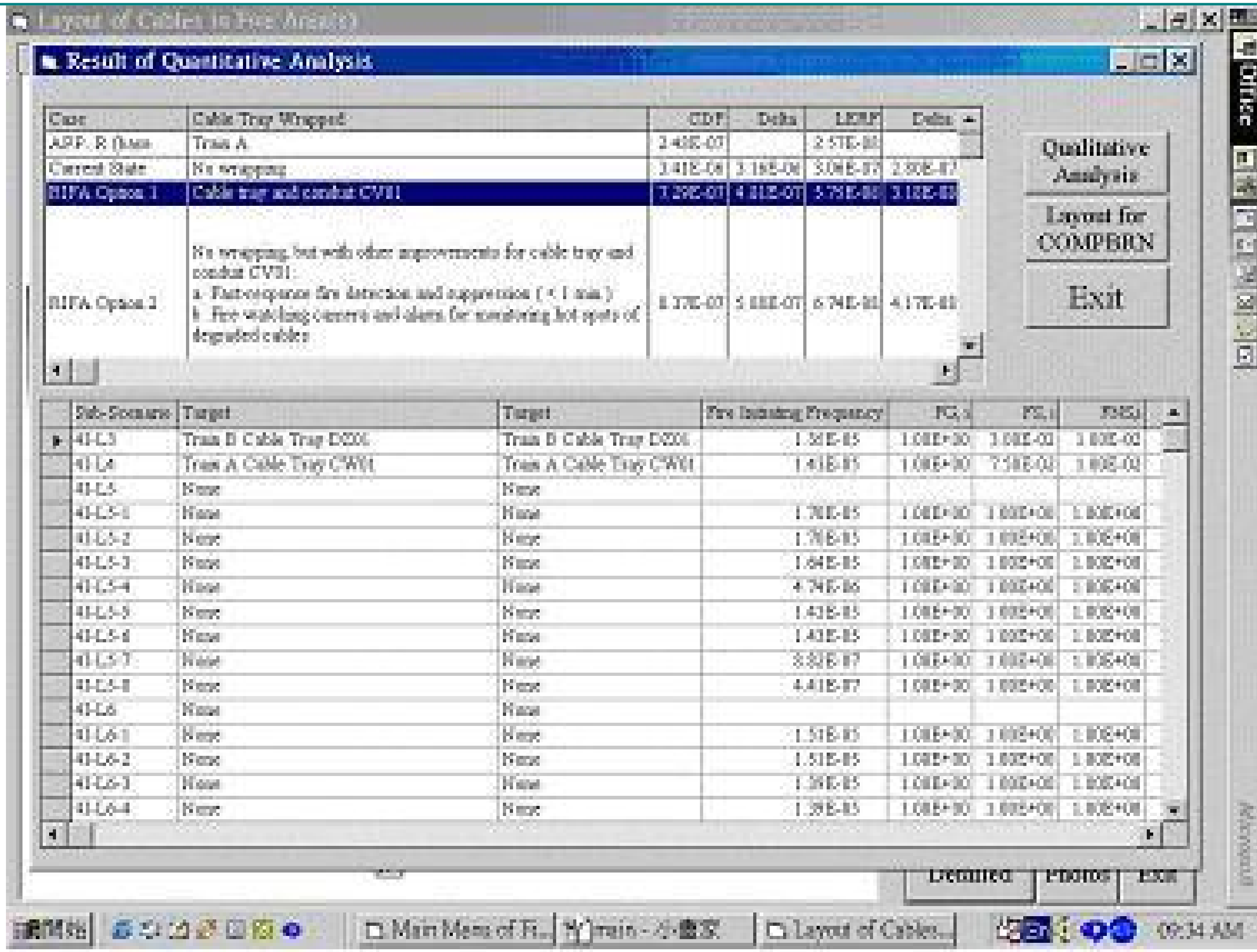
IV、Development of the SDP Tool, PRiSE (13 of 13)

- Three versions (BWR-4, BWR-6, PWR) of PRiSE were first released to inspectors for trial use in the beginning of 2005
- PRiSE 1.01 was released in November 2005 with responses to user's comments and new feature
- Current version includes internal events for power operation only
- INER plans to add new feature for containment integrity assessment (LERF)

V、Development of Risk-Informed Fire Analysis and ISI (1 of 3)

- Due to the unavailability of qualified fire wrap material for BWR-4 cable trays, plant people found that it was very difficult to meet the current requirements of Appendix R
- Use of the advanced PRA technology and associated code allows the Taiwan AEC/TPC staff to perform risk-informed fire analysis, post-fire safety shutdown function analysis, and assessment of cable tray fire wrap, to serve as the technical basis for Appendix R exemption requests

V、Development of Risk-Informed Fire Analysis and ISI (2 of 3)



Display of Wrap Options from RIFA

V、Development of Risk-Informed Fire Analysis and ISI (3 of 3)

- INER has also established the methodology for the evaluation and development of a pilot, plant-specific RI-ISI program for a BWR-6 plant in Taiwan
- The number of inspection elements selected in the RI-ISI evaluation has been decreased to only 50, representing a reduction of up to 56% in comparison with 113 inspections in the current ASME inspection program
- Extend containment ILRT interval from 3 times per 10 years to once per 10 years

VI、Conclusions (1 of 2)

- A powerful risk monitor, TIRM-2, has replaced TIRM to provide the basis of risk-informed applications in Taiwan
- With the capability of performing CDF and LERF calculations, the TIRM-2 becomes a very helpful tool in monitoring the risk of different plant states and provides further information directly for risk-informed applications
- The PRiSE has replaced the tables that the USNRC has developed for performing Phases 1 and 2 (and part of Phase 3) of the SDP

VI、Conclusions (2 of 2)

- The view and usage of these tables are complicated and time-consumed; so that the PRiSE has provided an alternative tool for Taiwan's resident inspectors to easily solve the PRA model in less than a minute

- With these credible assessment tools and other subsequent proposed cases of risk-informed applications, a new era of risk-informed regulation and applications has been initiated in Taiwan's nuclear society