Doosan Heavy Industries & Construction

An Improved Protection System for Zero SPV and CCF Elimination

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Gyeongju, Korea

Dec 4, 2017

10th International Workshop on Application of FPGA in NPP,
hosted by **DOOSAN** Heavy Industries & Construction Co., Ltd. in cooperation with the **IAEA** and **SunPort** SA.

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I. Introduction
- Background - CCF

- **CCF Requirements are continuously being increased to make sure safety & reliability of NPP**
  - ✓ ***As the Regulatory body requires the Safety analysis of CCF under LBLOCA as well as MSLB in accordance with BTP(Branch Technical Position) 7-19 which is quoted from the SRM on SECY-93-087***
  - ✓ ***DPS design change requested to add the other remain functions of PPS.***

- ***Original function of DPS***
  - ***AFAS due to the SG Low Level***
  - ***RX Trip when PZR or CNMT High Pressure***
- ***Required additional functions of DPS***
  - ***SIAS due to the PZR Low Pressure***
  - ***CIAS due to the PZR Low Pressure***
  - ***RX Trip due to the Steam Line Break***

PPS		DPS	
RX Trip	V	**RX Trip**	**V** (+SLB)
CIAS	V	**CIAS**	V
SIAS	V	**SIAS**	V
CSAS	V	CSAS	
MSIS	V	MSIS	
AFAS	V	**AFAS**	V
FHEVAS	V	FHEVAS	
CPIAS	V	**CPIAS**	V
CREVAS	V	**CREVAS**	V (TBD)

I. Introduction
- Background - SPV

- **SPVs are continuously being removed to enhance the reliability of NPP**
  - ***SSPS have still more than 80 SPVs***

For Example) Zero SPV CEDMCS

- ***After analyzing SPV of CEDMCS, finding 297 SPVs.***
- ***Finally, CEDMCS renovated to '0' SPV Systems***
  - *Step 1 : Identify – Define the single point vulnerability*
  - *Step 2 : Evaluate – Scrutinize all items*
  - *Step 3 : Design : Eliminate or mitigate SPVs.*
  - *Step 4 : Test – Verify & Validation of all items*
- ***Enhance the Maintain & Test Ability***
  - *On-line replacement of PCM or Electronic Cards*

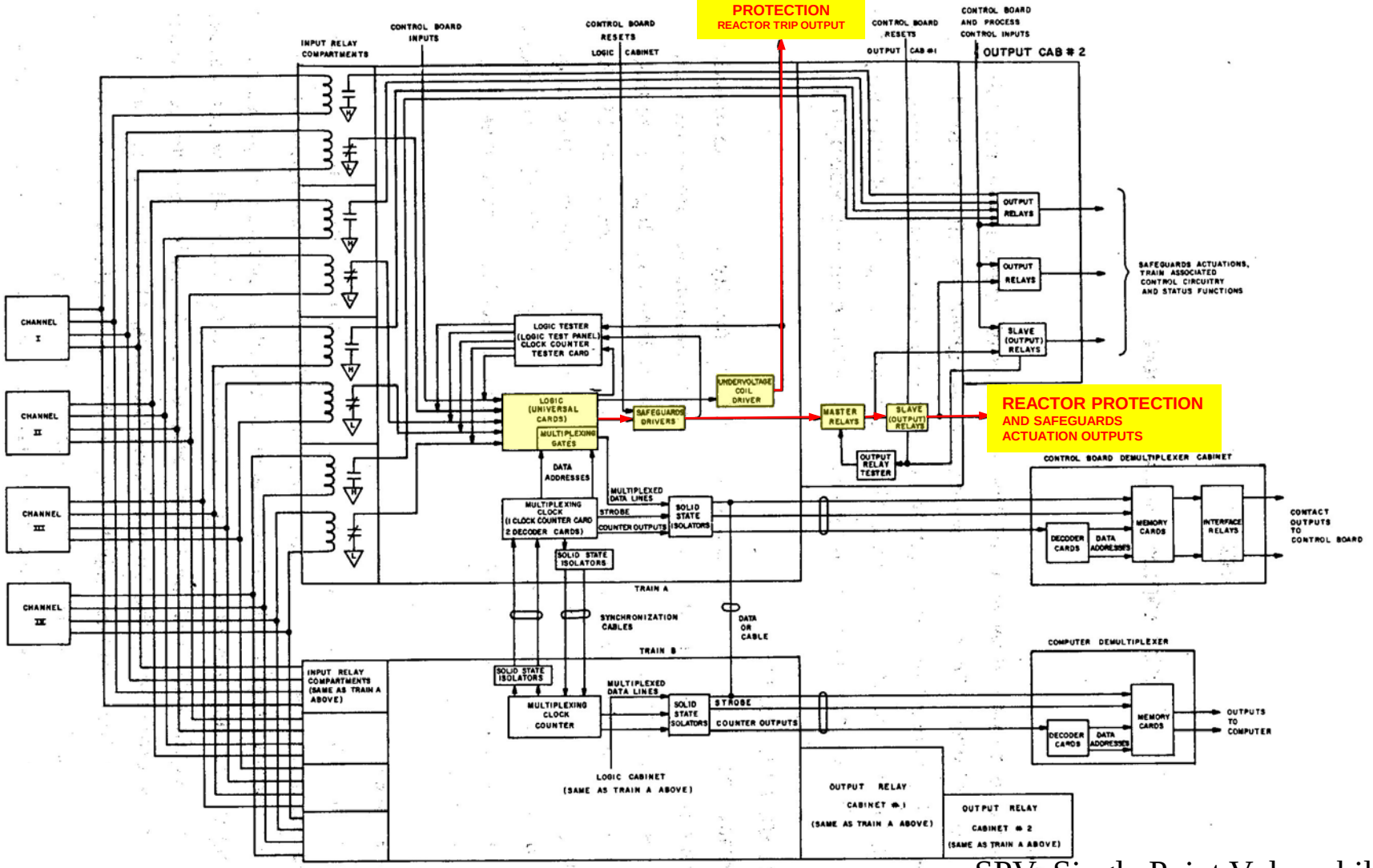


  - *Test by CRCS(3-Coil Type) & CEDMCS(4-Coil Type) MMI*

SPV: Single Point Vulnerability

I. Introduction
- Background - SPV

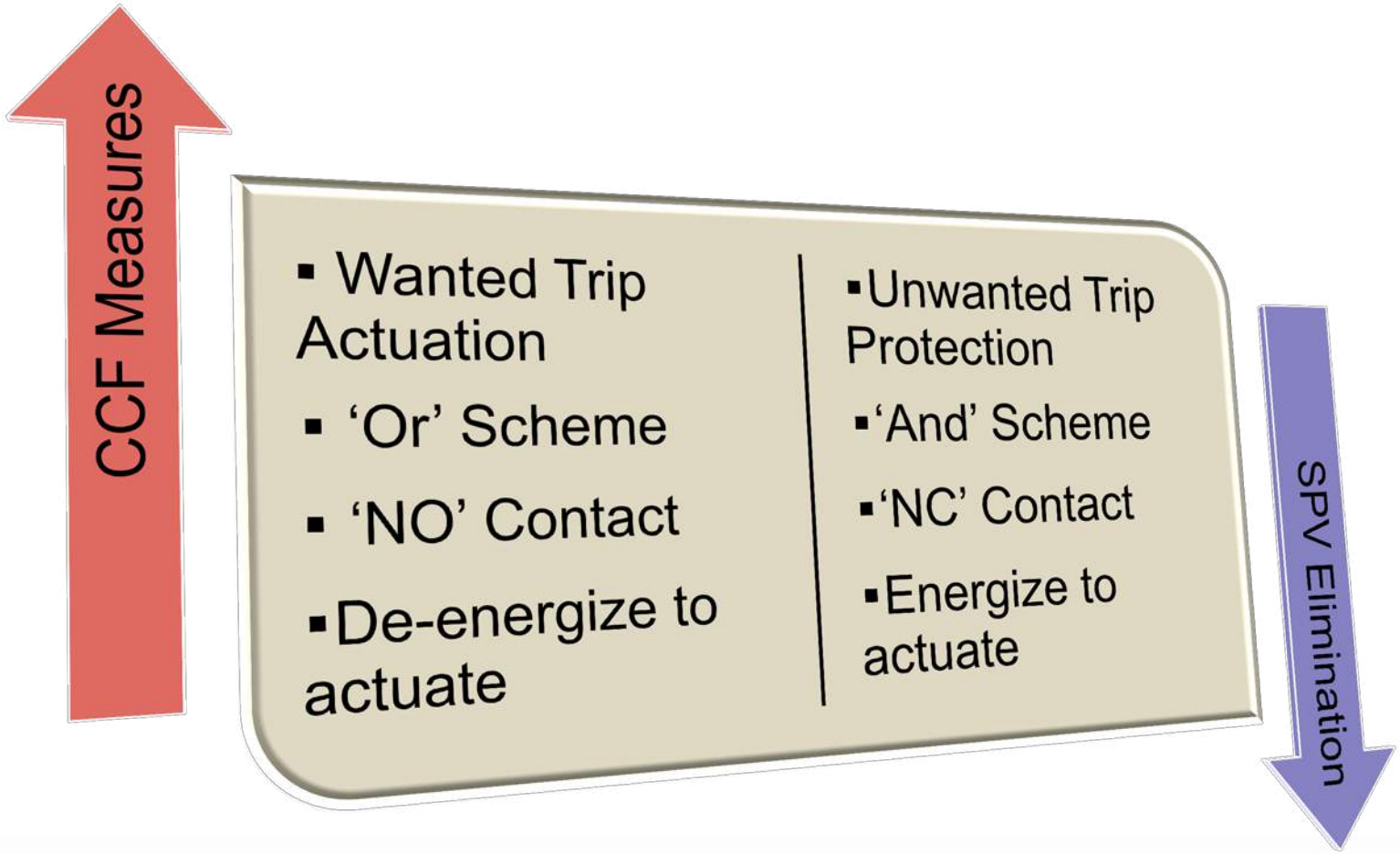
- **SPVs are continuously being removed to enhance the reliability of NPP**
  - ***SSPS have still more than 80 SPVs without Relays***



SSPS Block Diagram

I. Introduction
- Background – Differences of CCF and SPV

- **Differences in design characteristics between CCF and SPV**
  - ***Design Conflicts between CCF Measures & SPV Elimination:***



II. CCF measures for Protection System

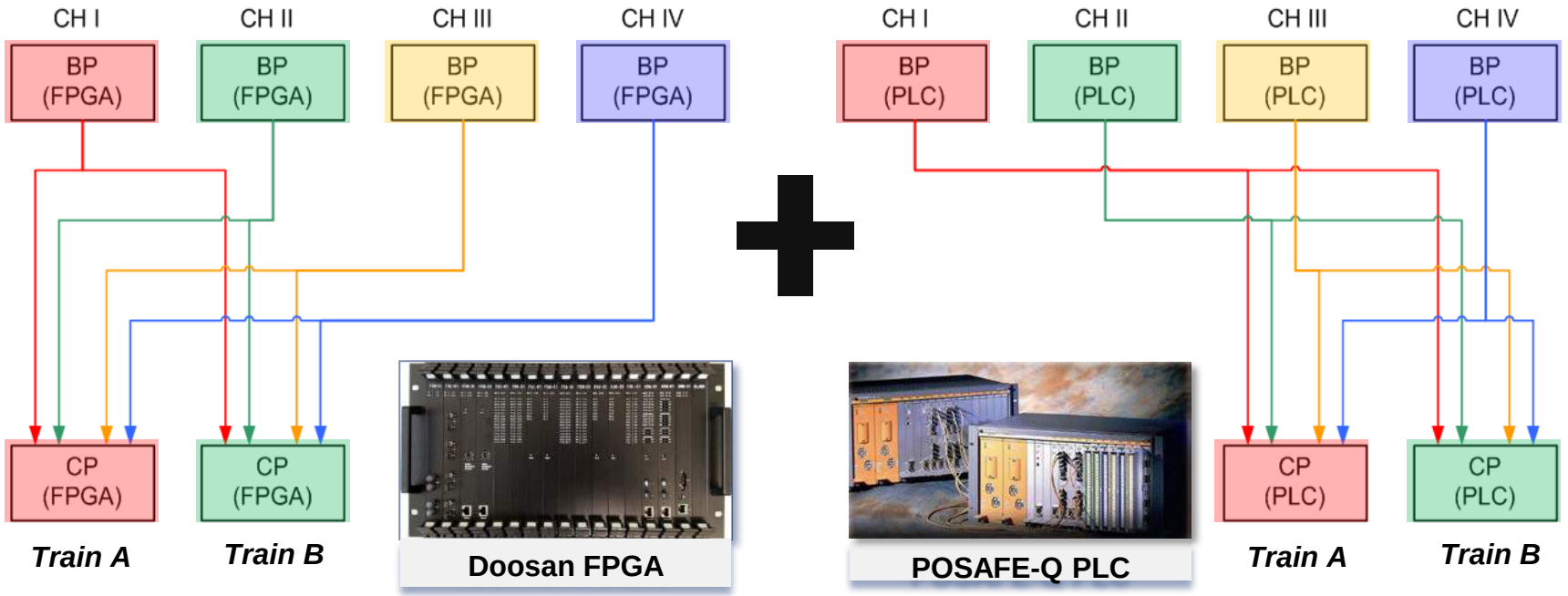
- Countermeasure for CCF Issues

- **Different Platform of PPS will resolve the CCF Issues without DPS**

✓ ***As is – Class 1E Protection System and Non-Class 1E DPS***

✓ ***To be – Class 1E independent Protection System using different platform***

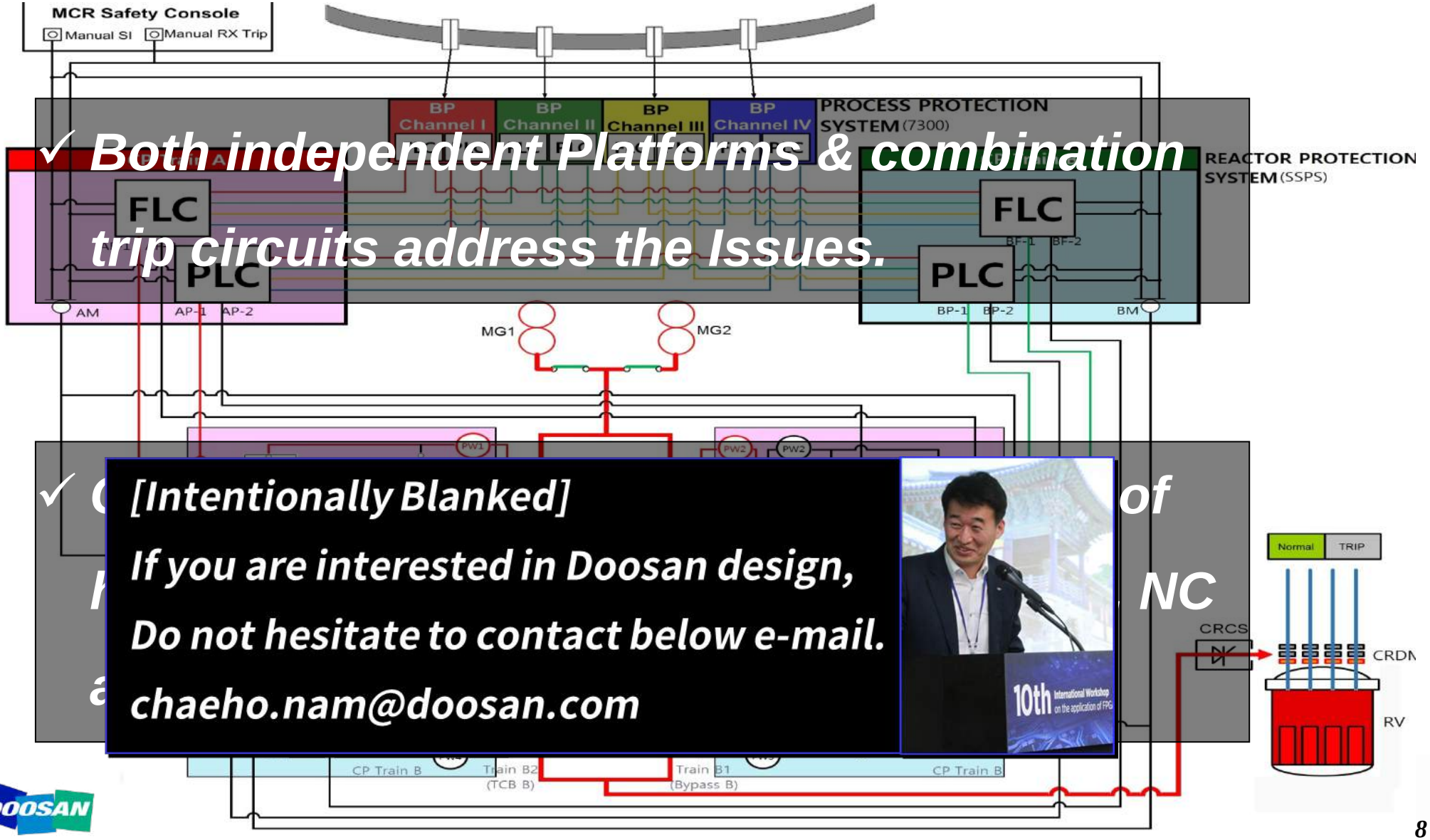
✓ ***Independent protection scheme designs using different controller platforms can mitigate ATWS by CCF***



II. CCF measures for Protection System

- Countermeasure for CCF Issues

- **Different Platform of PPS will resolve the CCF Issues (Rx Power 100%)**



✓ *Both independent Platforms & combination trip circuits address the Issues.*

✓ *C… of … NC …*

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II. CCF measures for Protection System
- Countermeasure for CCF & SPVs

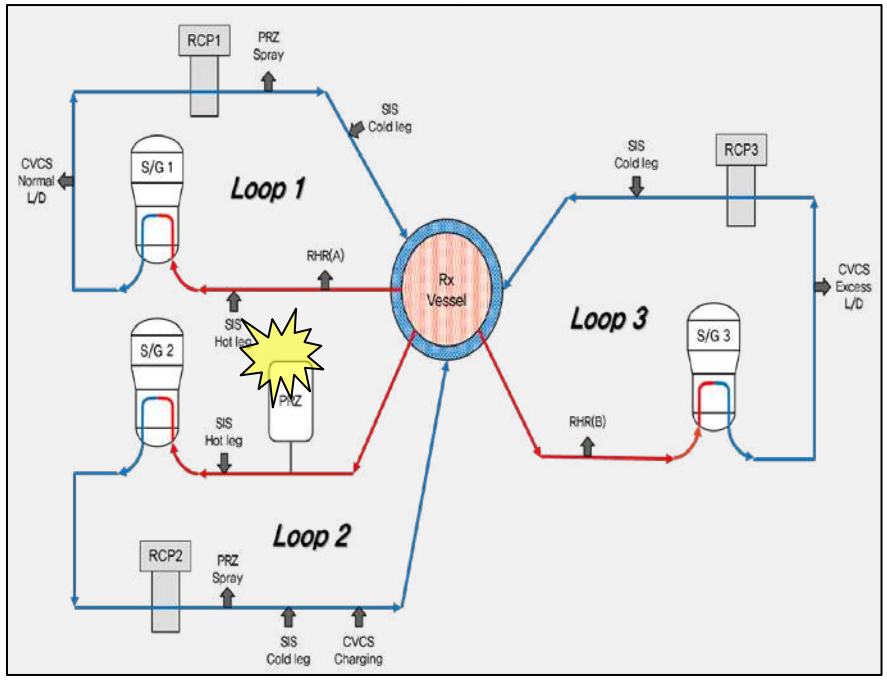
- **Redundancy & Combination IC remove the SPV of DI&C**

✓ ***The mutually independent protection system design using different controller platforms and combination trip circuits can mitigate ATWS at the condition of controller's CCF.***

Fail Mode \ Operation Mode		Normal Operation (Operability)	Safety Function (Reliability)
CCF of Controller	Open Fail	O	O
	Close Fail	O	O
	Toggle Fail	X	O
SPV	Trip Component	O	O
	Power Fail	O	O

III. Validation methods using Code Simulator

- Code Simulator is good for validation of newly developed system



Network

Hardwire

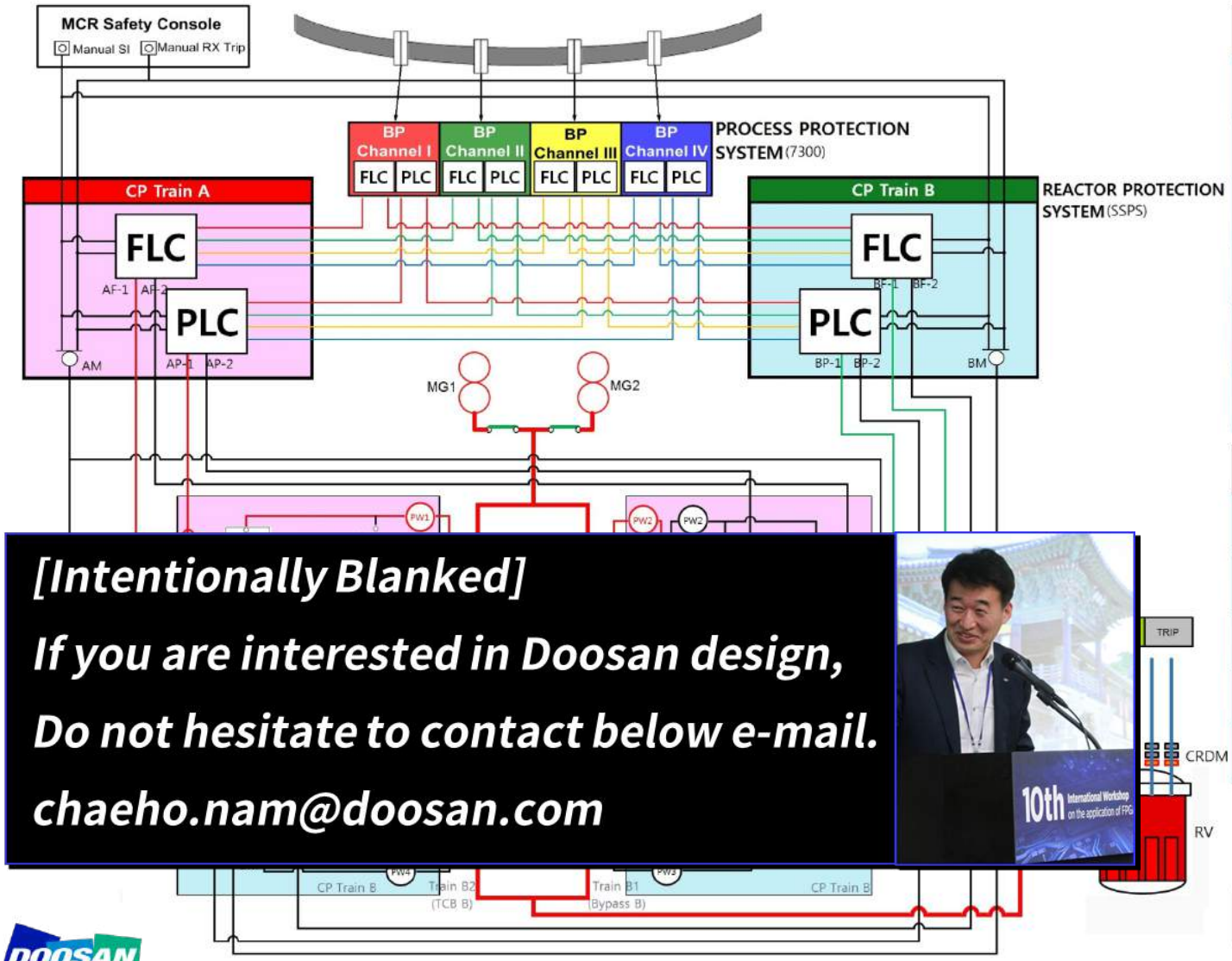
Design validation using code simulator with malfunction scenarios.

Ex) Pressurize crack

III. Validation methods using Code Simulator

- Code Simulator is good for validation of newly developed system

- **New Design for mitigating CCF and eliminating SPV**



ALARM			ESFAS
OT △T RCT TRIP	PRZ HI PRESS RCT TRIP	PWR RANGE HI FLUX RATE RCT TRIP	SIS
OP △T RCT TRIP	PRZ LO PRESS & P-7 RCT TRIP	RCS FLOW LO AT HI PWR RCT TRIP	CIS-A
CTMT PRESS HI SI RCT TRIP	SOURCE RANGE HI FLUX RCT TRIP	RCS FLOW LO AT LO PWR RCT TRIP	CIS-B
MANUAL RCT TRIP	INTMD RANGE HI FLUX RCT TRIP	SG 1,2,3 WTR LEVEL LO-LO RCT TRIP	CSS
MANUAL SI RCT TRIP	PWR RANGE HI FLUX HI SETPT RCT TRIP	TBN TRIP & P-7 RCT TRIP	FWIS
PRZ HI LEVEL RCT TRIP	PWR RANGE HI FLUX LO SETPT RCT TRIP	MSL PRESS LOW SI RCT TRIP	MSIS

CONTROL		PERMISSIVE	
C-1 High Neutron Flux Rod Stop Interlock	C-7 Loss of Load Interlock	P-4 Reactor Trip Permissive	P-11 Low Pressurizer Pressure SI Block Permissive
C-2 Overpower Rod Stop Interlock	C-8 Turbine Tripped Interlock	P-6 Source Range Block Permissive	P-12 High Steam Flow SI Block Permissive
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C-5 Low Power Interlock	C-16 Turbine Stop Loading Interlock	P-10 Nuclear At-Power Permissive	

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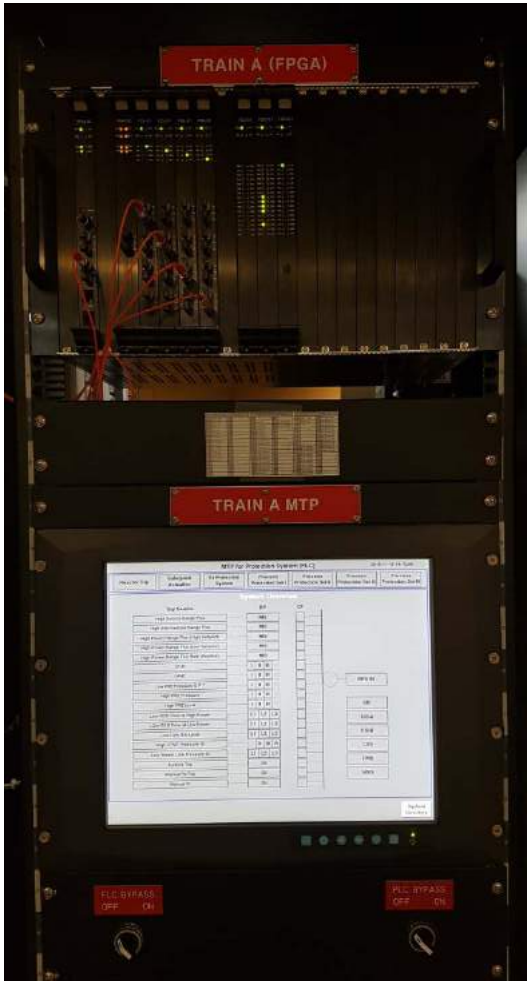
III. Validation methods using Code Simulator

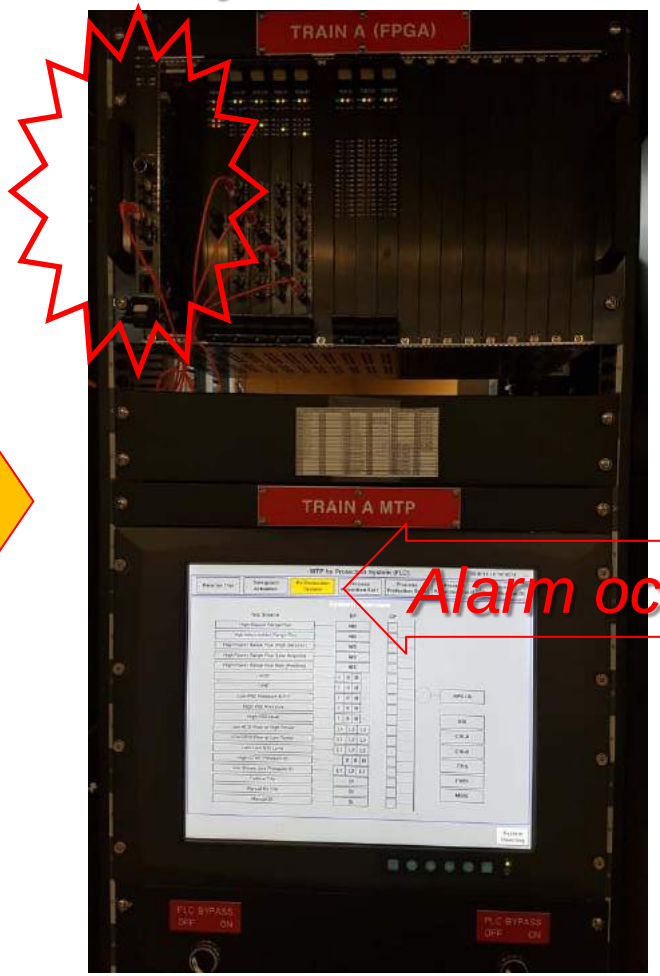
- Code Simulator is good for validation of newly developed system

- Case Study #1 SPV of FLC based Protection System

Normal Operation



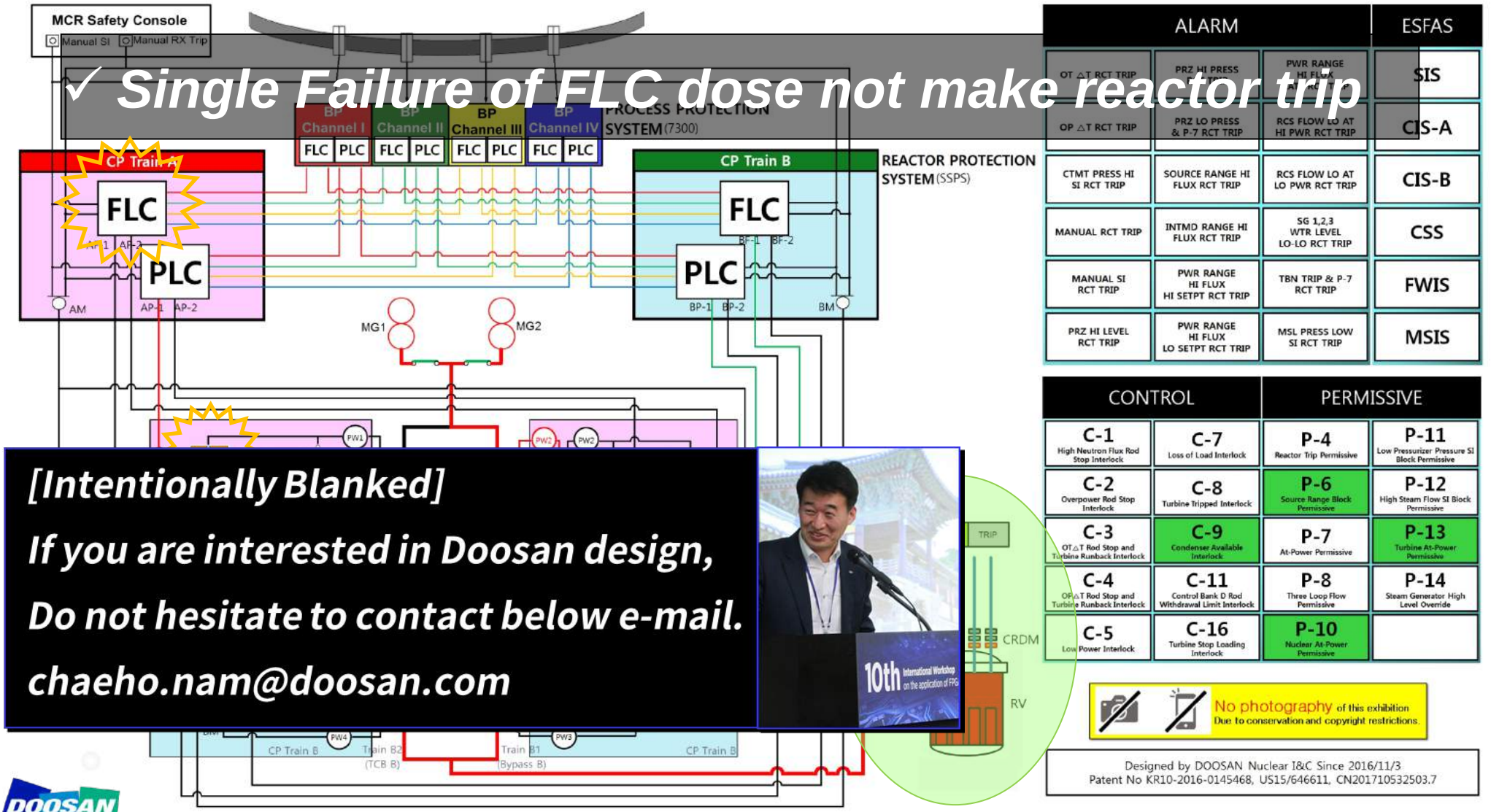
Reject the Card



III. Validation methods using Code Simulator

- Code Simulator is good for validation of newly developed system

- Case Study #1 **SPV of FLC based Protection System**



✓ *Single Failure of FLC dose not make reactor trip*

ALARM			ESFAS
OT △T RCT TRIP	PRZ HI PRESS	PWR RANGE HI FLUX	SIS
OP △T RCT TRIP	PRZ LO PRESS & P-7 RCT TRIP	RCS FLOW LO AT HI PWR RCT TRIP	CIS-A
CTMT PRESS HI SI RCT TRIP	SOURCE RANGE HI FLUX RCT TRIP	RCS FLOW LO AT LO PWR RCT TRIP	CIS-B
MANUAL RCT TRIP	INTMD RANGE HI FLUX RCT TRIP	SG 1,2,3 WTR LEVEL LO-LO RCT TRIP	CSS
MANUAL SI RCT TRIP	PWR RANGE HI FLUX HI SETPT RCT TRIP	TBN TRIP & P-7 RCT TRIP	FWIS
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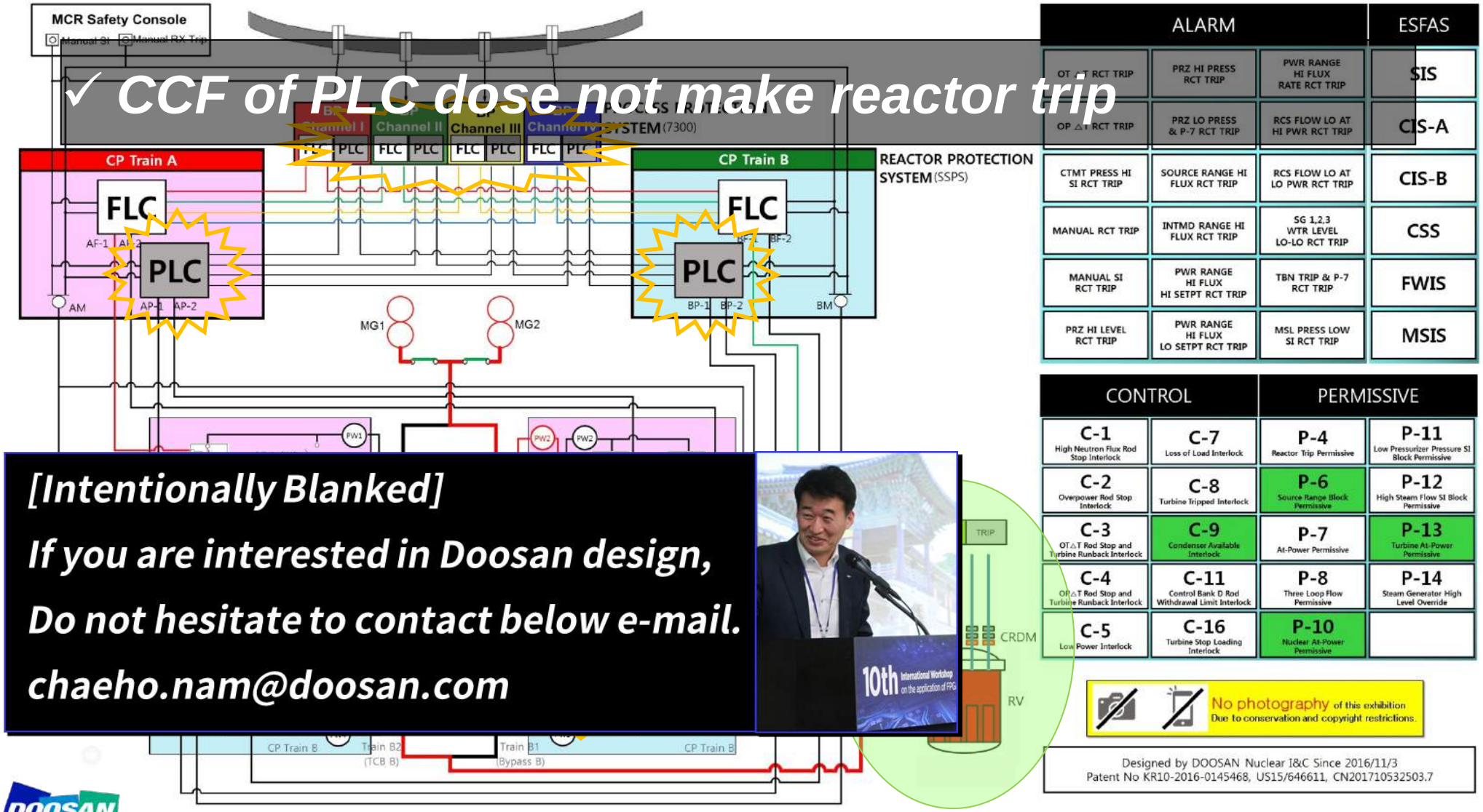
II. DI&C Solution

- Countermeasure for CCF Issues

- Case Study #2 **CCF of PLC based Protection System**



✓ *CCF of PLC dose not make reactor trip*

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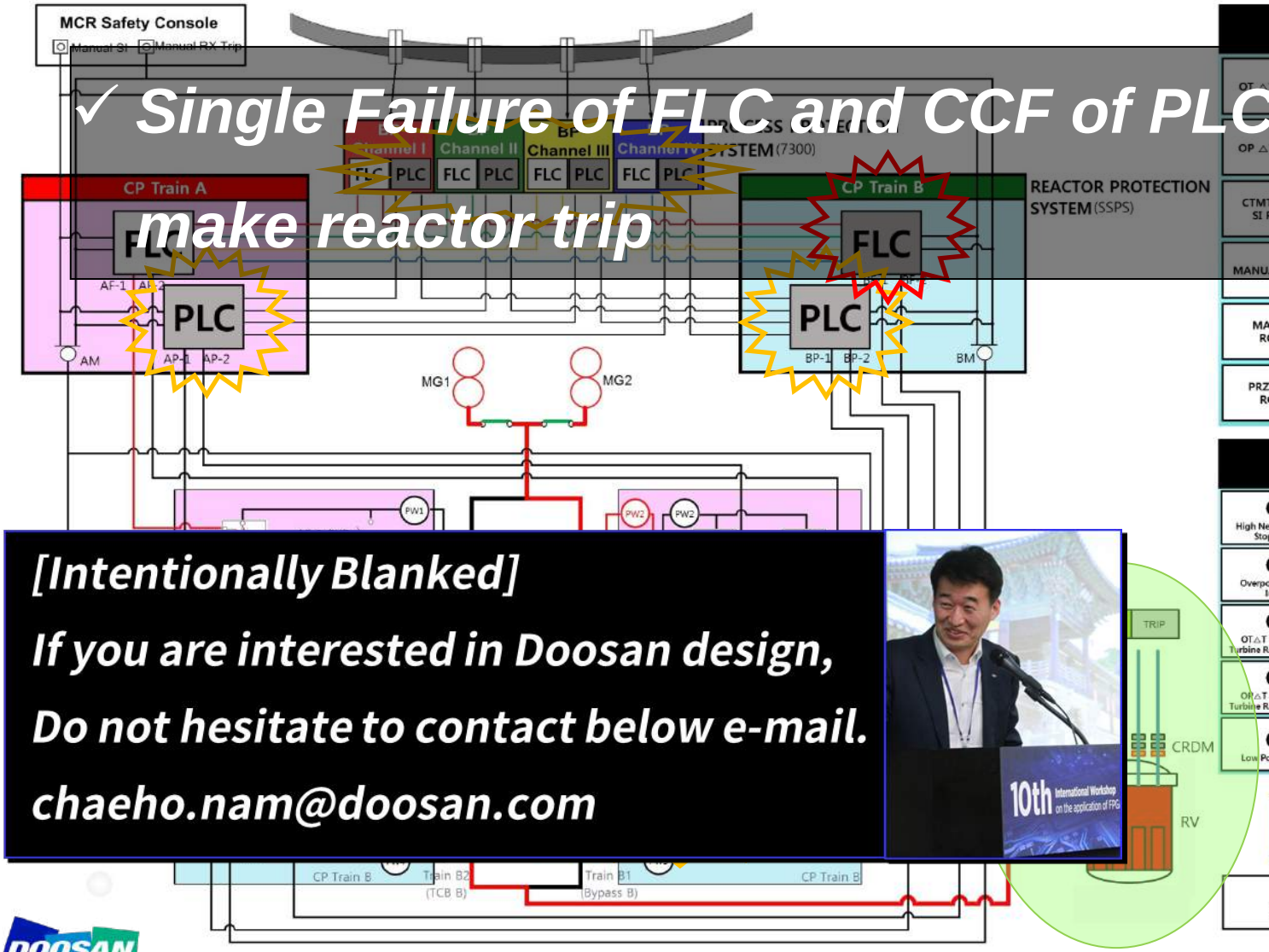
II. DI&C Solution

- Countermeasure for CCF Issues

- Case Study #3 **Combined PLC CCF & FLC SPV at Protection System**

✓ *Single Failure of FLC and CCF of PLC dose not make reactor trip*



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II. DI&C Solution

- Countermeasure for CCF Issues

- **Mitigate ATWS under PLC CCF Condition**

✓ *Even if CCF makes PLC RPS inoperable,*

Independent FLC RPS operable,

✓ *So, Don't warry about ATWS.*

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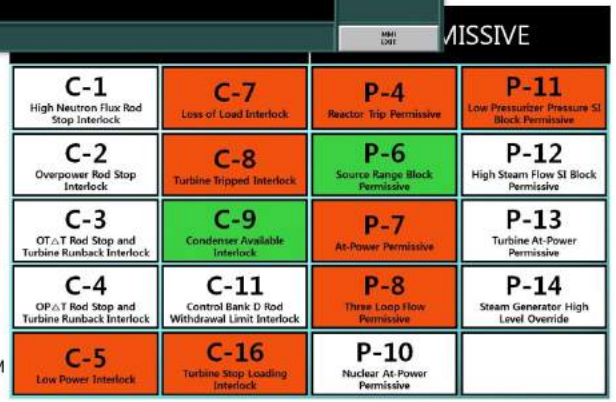

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II. DI&C Solution

- Countermeasure for CCF Issues

- **Mitigate ATWS under PLC CCF Condition**

✓ *Even if PLC RPS is inoperable and one FLC is disabled,……*

✓ *Don't warry about ATWS also.*

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ALARM			ESFAS
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Thank you for listening

✓ *After Coffee Break, Doosan will be demonstration.*

*Please joint the demonstration and enjoy it.^^*