中广核 CGN 核能 Nuclear Power

北京广利核系统工程有限公司
China Techenergy Co., Ltd.

The Application of FPGA-based FitRel Platform in Nuclear Power Plant Diverse Actuation System

Yinjie Chen
China Techenergy Co., Ltd (CTEC)
Dec 2017

善用自然的能量

* 此文件版权归北京广利核系统工程有限公司所有，未经许可任何单位或个人不得复制、翻印。

1.1 Introduction- CTEC

China Techenergy Co., Ltd.

A joint venture co-funded by China Nuclear Power Engineering Co., Ltd. (CNPEC, the controlling shareholder) and Beijing Hollysys Co., Ltd. (HOLLYSYS), provides full-life-cycle and end-to-end digital instrument and control (I&C) solutions to nuclear power customers.

We are

The **1st** enterprise having developed its own safety DCS product in China

The **1st** enterprise from China being able to provide an integrated DCS solution to nuclear power customers

The **1st** National Energy R&D Center for NPP Digital I&C System in the industry

Over 200 successful cases in nuclear power industry

1.1 Introduction- CTEC

FirmSys

A platform developed by CTEC with its own intellectual property for the safety applications, such as RPS (reactor protection system), ESFAS (engineered safety features actuation system) and PAMS (post accident monitoring system) , as well as the safety-related instrumentation and control systems.

FitRel

A general platform developed based on the FPGA (Field Programmable Gate Array) technology for the diversity of safety systems. It is applicable to nuclear power plants of various technologies.

HOLLiAS-N

A matured platform for the non-safety DCS which has already been used for many nuclear power plants under construction in China.

SpeedyHold

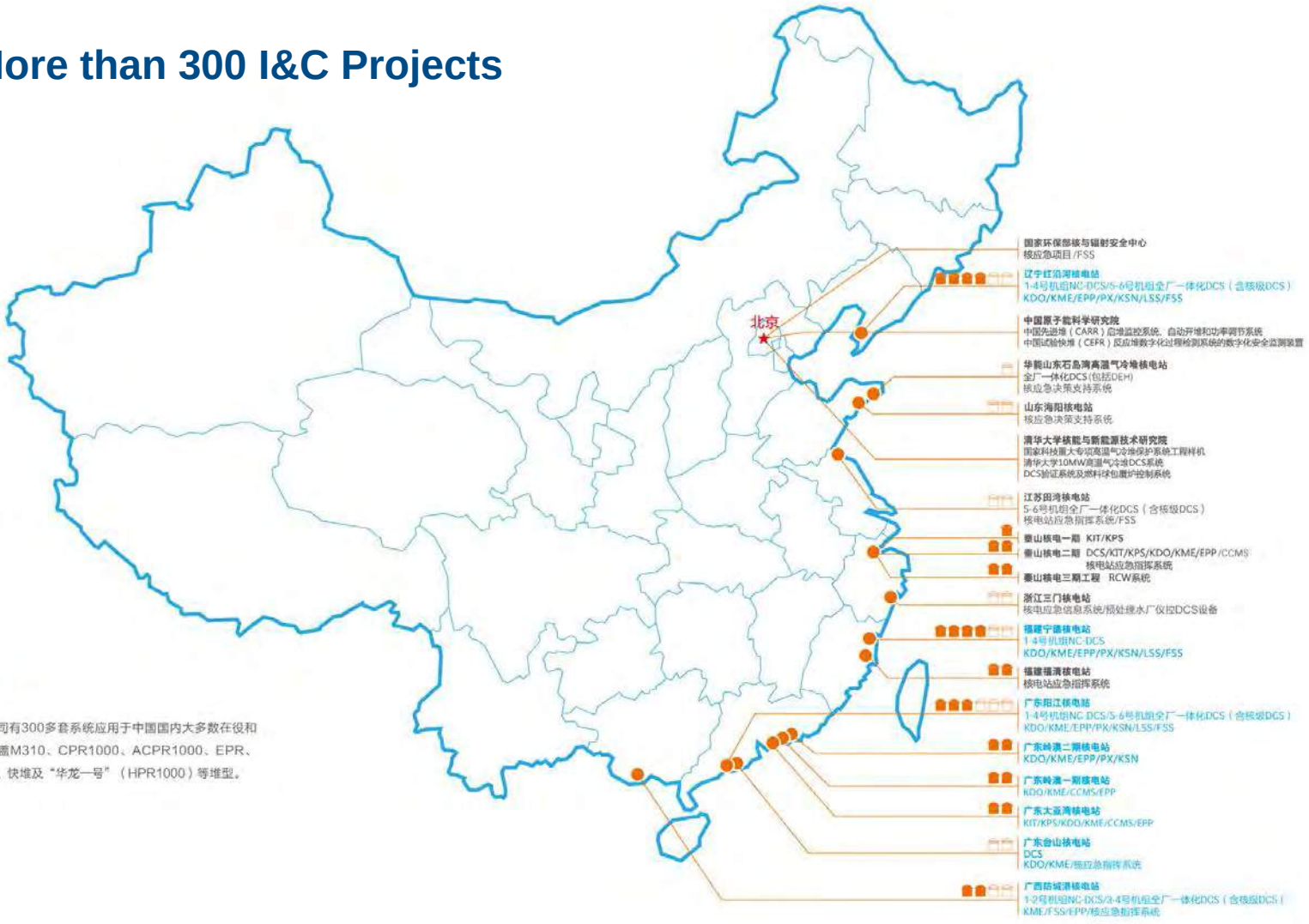
A platform designed for various specific NPP DCS, such as KDO, KME, EPP, LSS, TRA, and KSN, which is mainly featured in fast and high- accuracy data acquisition and wave record.

EmInfoSys
核事故应急辅助决策系统

A self-developed nuclear emergency information management system platform, which can be customized to the application in nuclear power plants, power-generation groups, and provincial and national levels.

1.1 Introduction- CTEC

More than 300 I&C Projects



项目布局

目前，广利核公司有300多套系统应用于中国国内大多数在役和新建核电站，覆盖M310、CPR1000、ACPR1000、EPR、AP1000、HTR、快堆及“华龙一号”（HPR1000）等堆型。

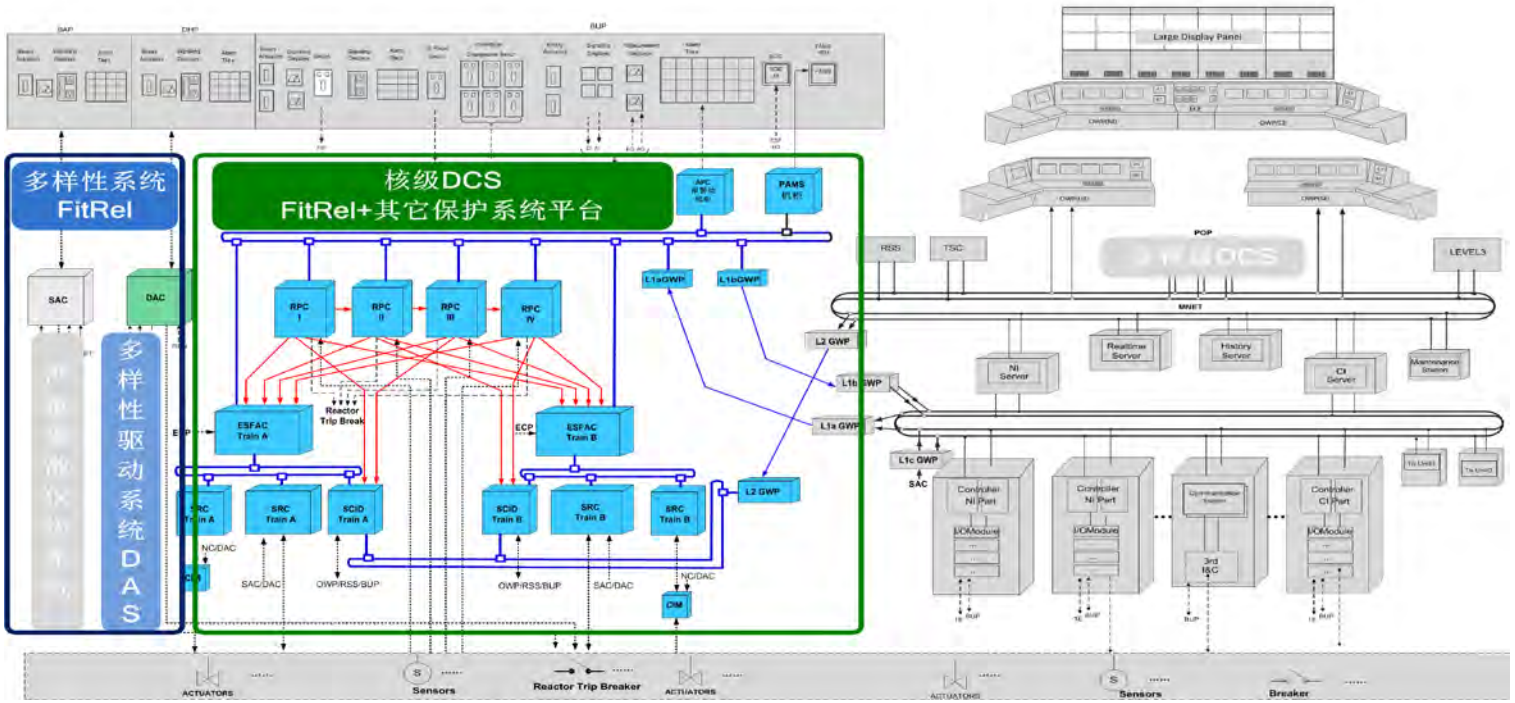
1.2 Introduction- FitRel Platform Positioning

FitRel

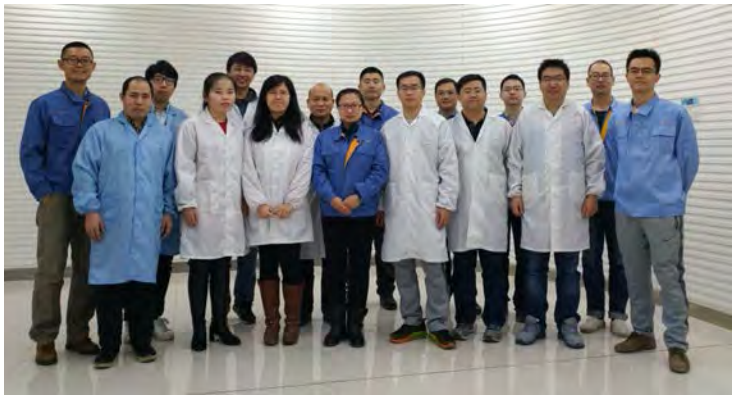
Fit and Reliability

General FPGA-based NPP I&C

- DAS (Diversity Actuation System) for RPS as Non-safety.
- Achieving protection function with another safety I&C protection system.
- Protection system for specific application.



1.3 Introduction- FitRel Platform Roadmap



National 863 Program(sub-project)
The Research of Diversity technology of I&C in NPP

sub-project
Development of diversity I&C device in NPP

Development of FitRel-1000 platform

FitRel-1000 platform released

Yangjiang Unit 5,6

Hongyanhe Unit 5,6

Tianwan Unit 5,6

Fangchenggang Unit 3,4

2012 | 2013 | 2014 | 2015 | 2016 | 2017

1.4 Introduction- Standard

- **Logic design: IEC-62138 category B**
  IEC-62566 ,NUREG/CR7006
- **Logic V&V : IEEE1012 Class 3**
- **Hardware design : IEC-60987, IEC 60780**
- **Environment Test :**
  IEC 60068-2 (Class 3) 。
- **Seismic Test :**
  Seismic category 1 , GB/T 13625
- **Electromagnetic Compatibility :**
  IEC 62003 (Class 3)

TÜV Rheinland ISTec GmbH
Institut für Sicherheitstechnologie

ISTec GmbH · Postfach 12 13 · 85740 Garching

China Techenergy Co. Ltd – CTEC
Mr. Gao Yubin
Building 5, No. 5 Yongfeng Road
Haidian District
Post Code: 100094
Beijing
P.R. China

Garching-Forschungszentrum
Boltzmannstr. 14
85748 Garching b. München
Telefon +49 89 5151 466-0
Telefax +49 89 5151 466-20

Am Grauen Stein
51105 Köln
Telefon +49 221 806-5623
Telefax +49 221 806-36 5623

145050222 Miedl/Seidenscl ☎ 089 5151466-41 December 21th, 2016
2016-0194

USt-/VAT-Id.-No.: DE 811 345 176

Contract No.: 030-GN-B-2016-C21-00012
Project name: FitRel platform category B software third party verification and validation (V&V) project

Dear Mr. Gao Yubin,

With contract no. 030-GN-B-2016-C21-00012, ISTec was commissioned to carry out the third party verification and validation (V&V) for FitRel platform software performing category B functions.

Enclosed please find the signed Certificates for the safety modules:

Certificate AI 2016-12-09
Certificate AO 2016-12-09
Certificate DI 2016-12-09
Certificate DO 2016-12-09
Certificate FB 2016-12-09
Certificate Libero 2016-12-09
Certificate MPU 2016-12-09
Certificate MT 2016-12-09
Certificate NCU 2016-12-09
Certificate Platform 2016-12-09

We would like to thank you for your support and are looking forward to continuing our cooperation.

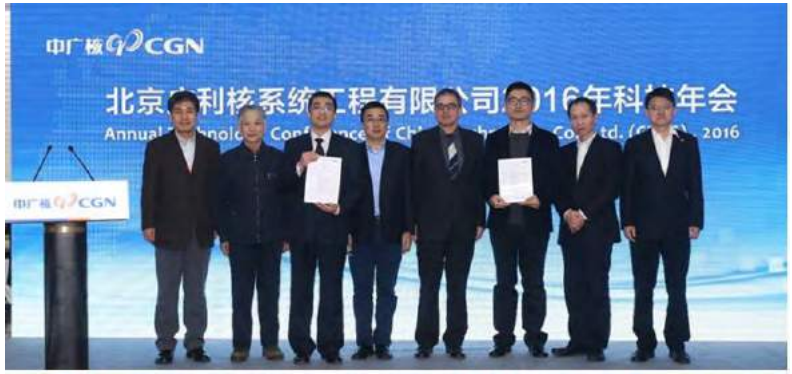
Sincerely yours,
TÜV Rheinland ISTec GmbH – Institut für Sicherheitstechnologie
Department I&C, Safety and Security

i.V. Dr. A. Lindner i. A. D. Seidenschwarz

Encl.

cc: lia, mid, pli, wos

Geschäftsführer: Bruno Kuckartz Sitz der Gesellschaft: Garching Commerzbank AG Köln IBAN: DE76 3708 0040 0370 4300 00
Handelsregister-Nr.: 102243 SWIFT/BIC: DRESDEFF 370



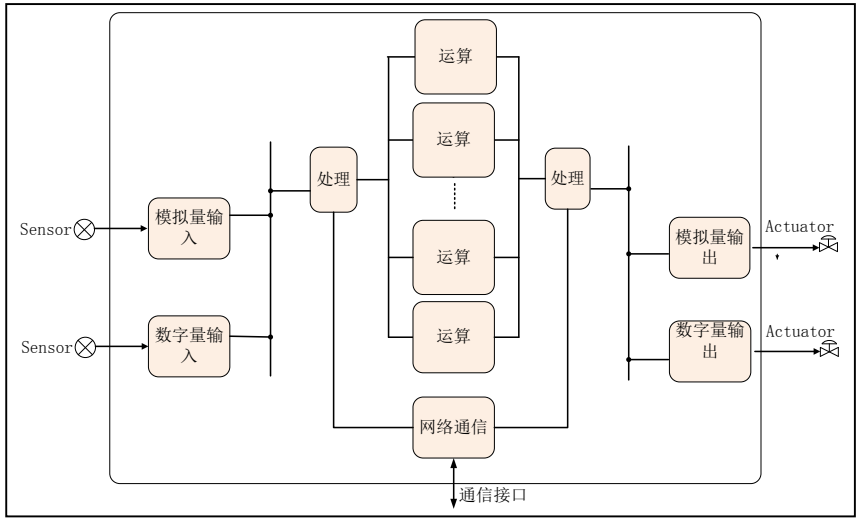
1 Introduction

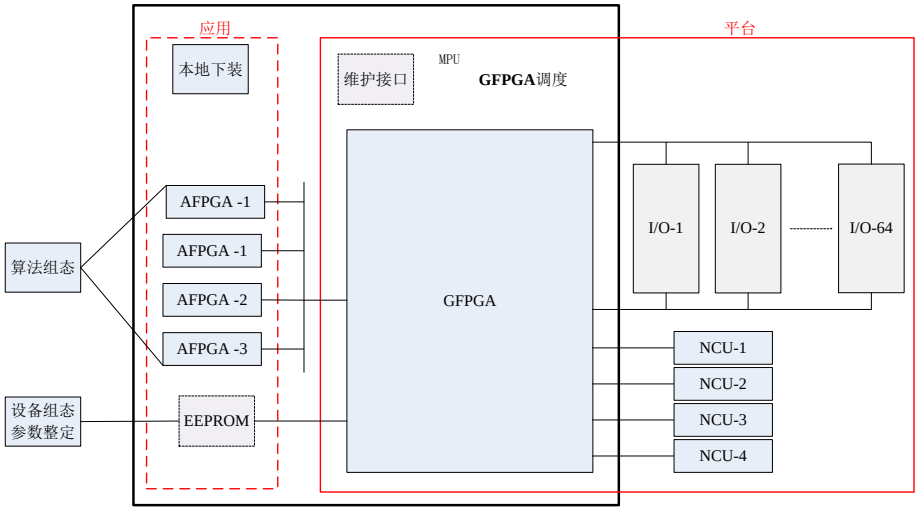
2 R&D of FPGA-based FitRel Platform

3 Application in ACPR1000 Project

4 Conclusion

2.1 Architecture Design





- Take the advantage of **parallel processing** of FPGA, improving the speed and efficiency of arithmetic operation;
- Retain the advantage of the modern centralized DCS, and the configuration, management and scheduling of the entire system are performed by the main process unit, therefore, the system still has a strong ease of use;
- **Generic FPGA (GFPGA)and Application FPGA (AFPGA)**;
- 4 AFPGAs support complex algorithm processing.

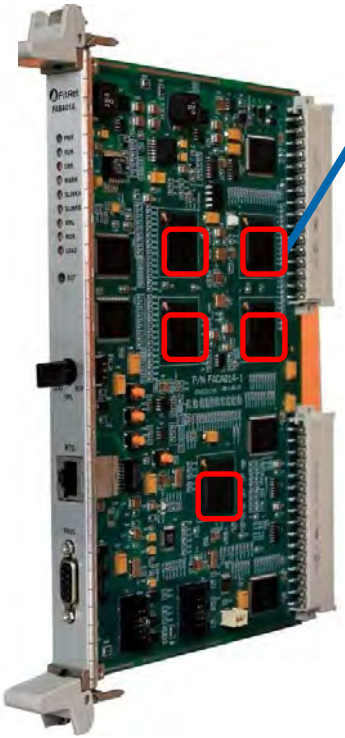
2.2 Functional Safety Design

SIL3

Component	Function block	Diagnose measure	DC
FPGA	Clock	independent time base and time window	H 99%
	Data integrity	CRC32/64	H 99%
	Comm interface	Safety protocol	H 99%
	Application logic block	Built-in self test	M 90%
Clock	Quartz, Oscillator,PLL	WDT of independent time base and time window	H 99%
Digital input		Redundant input signal compare	M 90%
Digital output		Read back & dynamic self-test	M 90%
Analogue input		Dynamic self-test	M 90%
Power supply	Over-voltage Under-voltage	Voltage monitor and compare	H 99%
Safety communication		Transmission errors; Repetitions; Deletion; Insertion; Re-sequencing; Corruption; Delay; Masquerade.	H 99%

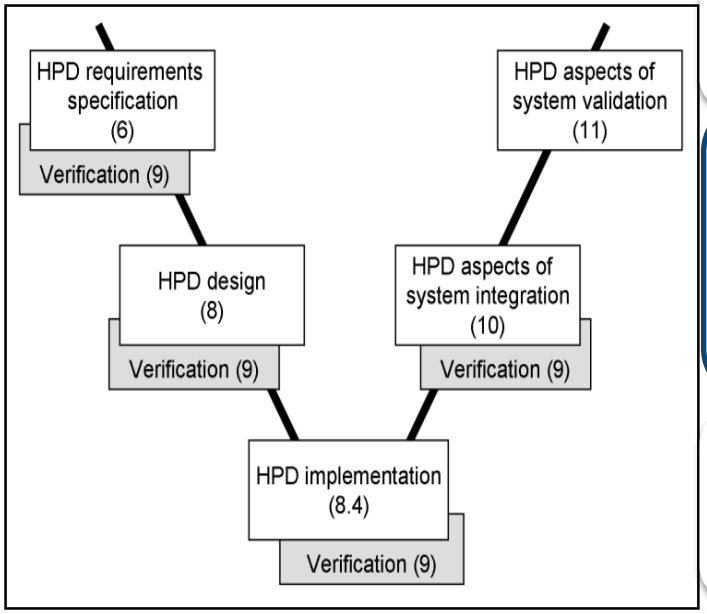
2.3 Hardware and Mechanical Design

- 19 inch standard
- 40U installation space
- Seismic class I



- FPGA-based
- High DC SIL3
  - Power
  - Clock
  - Comm…
- Reliability
  - EMC
  - Cooling
  - Derate …

2.4 HPD Design



Traditional "V cycle" model

Design Phase

Synchronous design

It makes the design simpler and more deterministic, and it facilitates verification and testing;

Modular design

use of smaller, simpler modules as opposed to one large;

Segregating the primary functions

maintenance function like transmitting diagnose information;

Avoid using complex native blocks

FitRel platform supplies sufficient application algorithm blocks without any the third party IP, even the basic blocks like addition, multiplication, divisions ,etc.

2.4 HPD Design

Implementation phase

- Synthesis and place and route
- Static Timing Analysis (STA)

Verification and validation phase

- RTL simulation
- divide et impera' (divide and conquer) principle

1 Introduction

2 R&D of FPGA-based FitRel Platform

3 Application in ACPR1000 Project

4 Conclusion

3.1 Application projects

2015年 Unit5&6 Yangjiang NPP DAS

2015年 Unit5&6 Hongyanhe NPP DAS

2016年 Unit5&6 Tianwan NPP DAS & ECP

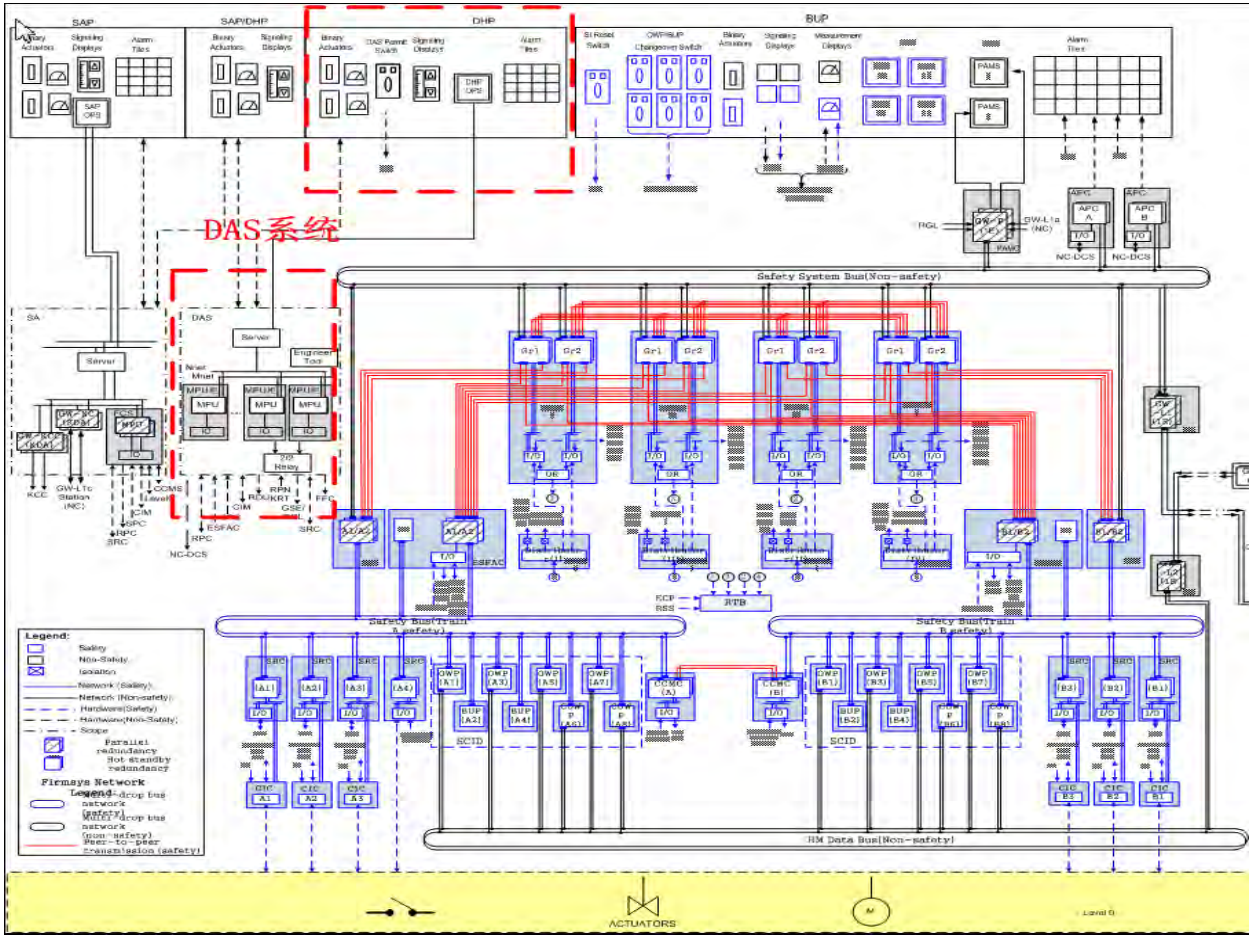
2016年 Unit5&6 Fangchenggang DAS（Hualong One）

* 此文件版权归北京广利核系统工程有限公司所有，未经许可任何单位或个人不得复制、翻印。

3.1 DAS Architecture

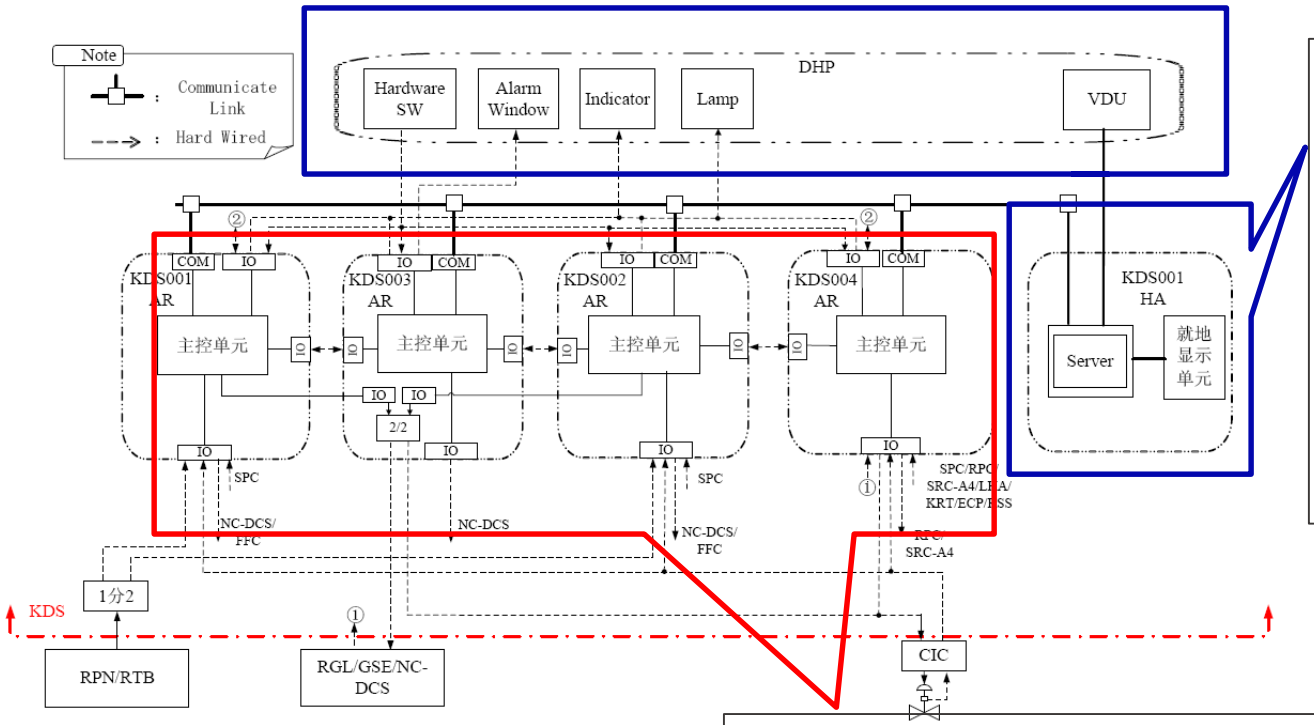
DAS function

- Providing diversified automatic signals to actuate reactor trip and the chosen engineering safety features
- Providing diversified manual reactor trip and actuation of the engineering safety features
- Providing diversified independent indicators for chosen power plant parameters



* 此文件版权归北京广利核系统工程有限公司所有，未经许可任何单位或个人不得复制、翻印。

3.1 DAS Architecture



LEVEL2：

- Server+VDU
- Hardwar manual
- Display instrument
- Indicator
- Maintenance tool

LEVEL1：

- 2 auto actuation logic cabinets
- 2 manual actuation logic cabinets

2oo2

* 此文件版权归北京广利核系统工程有限公司所有，未经许可任何单位或个人不得复制、翻印。

3.2 DAS Performance

Technical Index	
FPGA memory	≤70%
Load of network	≤40%
Analog input signal	±0.1%
Analog output signal	± 0.1%
Rejection rate :	0.01/instruction
Spurious rate	0.1 time per year
Availability	＞99.99%
Response time	150ms

DAS and RPS Diversity Analysis Result			
Dimension	DCE WT	INH	Score
Design	1	0.5	0.5
Equipment Manufacture	0.25	0.075	0.3
Logic Processing Equipment	0.64	0	0
Functional	0.6	0.6	1
Life-Cycle	0.683	0.4098	0.6
Signal	0.867	0.72	0.83333
Logic	0.733	0	0
Score			1.287184908

＞1.0

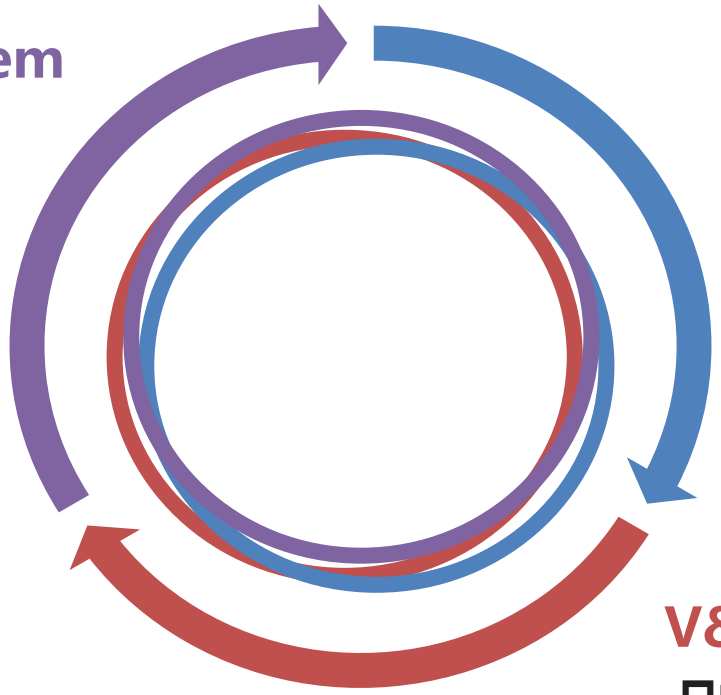
3.3 Difficulties

Diversity problems

- It is recognized by most of the countries according to NUREG/CR-6303/7007
- Difficult for GDA of UK，Simple Hardware Technology

Usability problem

- Graphical algorithm configuration tools;
- Algorithm download based on Ethernet technology.



V&V problems

- Build FitRel simulation platform carried full validation and verification.

1 Introduction

2 R&D of FPGA-based FitRel Platform

3 Application in ACPR1000 Project

4 Conclusion

4 Conclusion

1 Achievement

The first FPGA-based digital I&C platform applied in diversity actuation system in China. The application was a success with 0 defect for initial powering on. Currently, it is close to commercial operation, and none of FPGA-related problems has occurred.

Features of simplicity, reliability and usability, it is highly appreciated and praised by engineering design teams and owners.

2 Problems

Usability Problems

Diversity Problems

V&V Problems

3 Expectation

Broader and more widespread application of FitRel platform.

FPGA Technology will be much more acceptable .

* 此文件版权归北京广利核系统工程有限公司所有，未经许可任何单位或个人不得复制、翻印。

Thank You!

* 此文件版权归北京广利核系统工程有限公司所有，未经许可任何单位或个人不得复制、翻印。