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Preparations for the control of HL-2M first plasma campaign

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ABSTRACT

- HL-2M main components assembly will be accomplished in the end of 2019 and first plasma campaign is expected in 2020.
- The developed PCS consists of plasma discharge scheduling platform, feedback control system, timing control system and central interlock system. A brief introduction of PCS is included.
- In order to minimize the risks and difficulties of first plasma control, only small parts of PF coils are used in first plasma campaign.
- Two scenarios are designed by using a MATLAB-based tool, recently developed in SWIP. Ohmic initial magnetization and VDE are not expected.

BACKGROUND

•HL-2M is a medium-size copper tokamak under construction in China as a modification to HL-2A, with Ip=3MA, R=1.78m, a=0.65m, Bt=2.2T and k≈2.

装置/参数	HL-2A	HL-2M
Major radius	1.65m	1.78m
Minor radius	0.4m	0.65m
Aspect ratio	4.1	2.8
Flux swing	2.5Vs	>14 Vs
Plasma current	0.45MA	2.5MA (3 MA)
Toroidal field	2.8T	2.2 T (3.0T)
Triangularity	<0.5 (DN)	>0.5
Elongation	<1.3 (DN)	2
Heating	>10MW	>25MW
Null	SN	Flexible

Coil parameters of HL-2M

Coils	R(m)	Z(m)	W(m)	H(m)	θ	Ncoil	I_{max} (kA)
CS	0.748	0.0	0.144	3.560	0	96	110
PF1	0.912	0.185	0.068	0.401	0	28	14.5
PF2	0.912	0.586	0.068	0.401	0	28	14.5
PF3	0.912	0.987	0.068	0.401	0	28	14.5
PF4	0.912	1.388	0.068	0.401	0	28	14.5
PF5	1.092	1.753	0.201	0.238	0	28	38
PF6	1.501	1.790	0.275	0.164	0	27	38
PF7	2.500	1.200	0.320	0.238	64	28	42
PF8	2.760	0.480	0.201	0.238	0	28	38

•16 up-down symmetric PF coils and one CS coil are powered separately, providing more control freedom and flexibility for advanced shape exploration

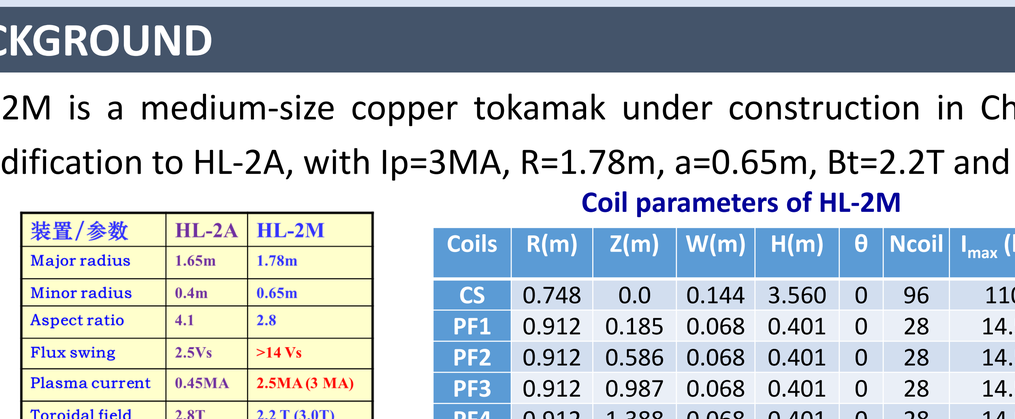

Fig.1 Representative plasma shape configuration for HL-2M

Development of plasma control system

The framework of PCS is consisted of **discharge scheduling platform**, **feedback control system**, **timing control system** and **central interlock system**.

➢ The **discharge scheduling platform** incorporates a Web server based on eXtensible Markup Language (XML) for the preset of discharge parameters and contains a waveform server based on MATLAB.

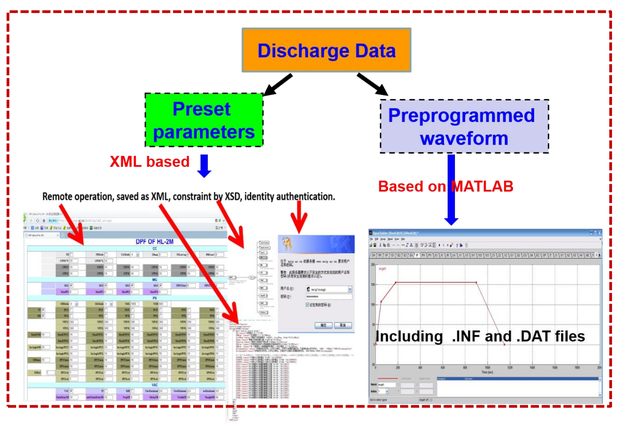

Fig.2 framework of discharge scheduling platform

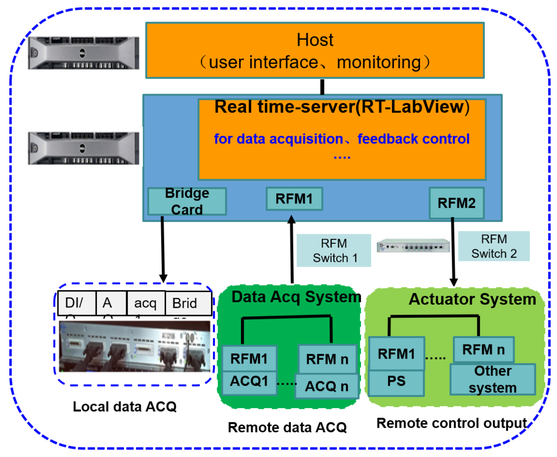

Fig.3 PCS structure for HL-2M

➢ Timing control system

- generates the trigger according to the desired sequential defined in XML
- 96 output channels of 5V TTL trigger, 16 input channels of trigger condition

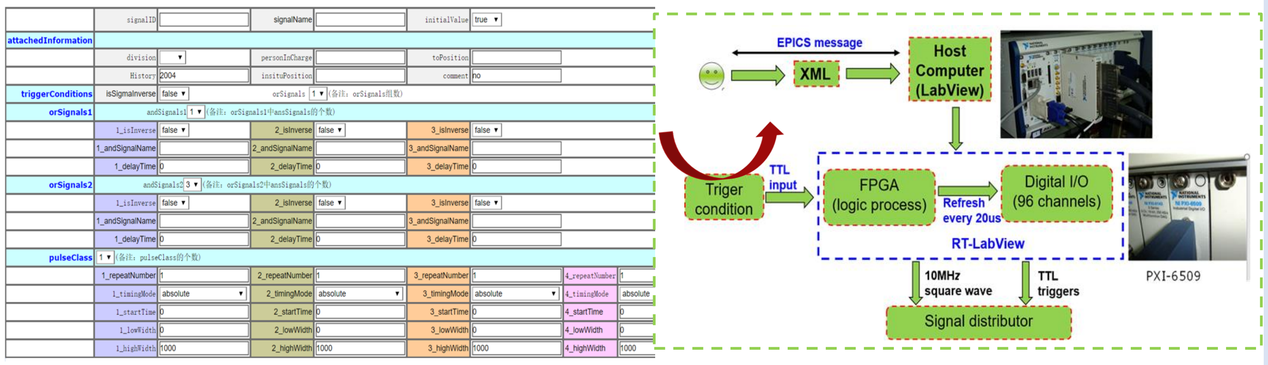

Fig.4 framework of timing control system

➢ Central interlock system

System monitoring interface, detection and response to off-normal events have been implemented in the newly developed central interlock system (CIS) based on WinCC and PLC.

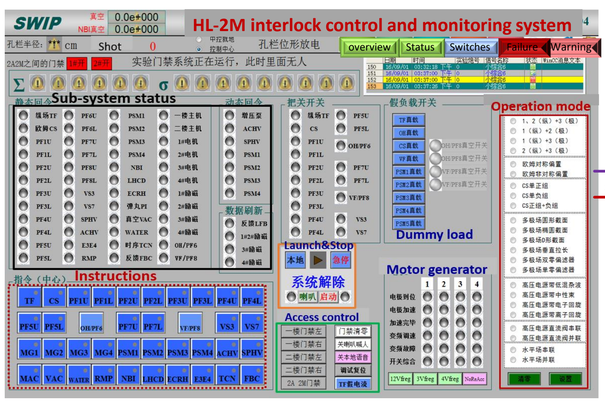

Fig.5 Monitoring interface with Siemens WINCC

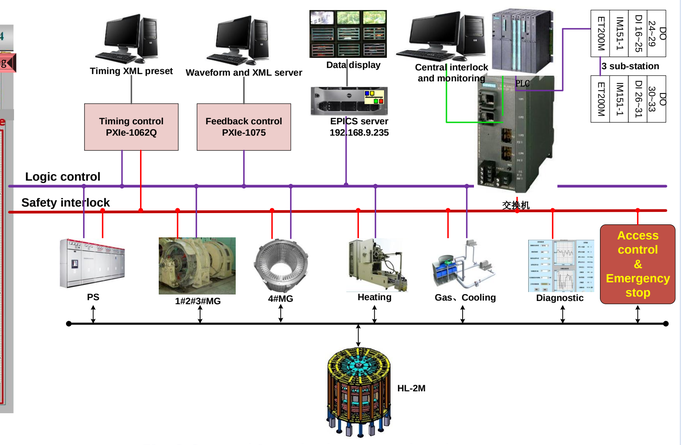

Fig.6 Central interlock system hardware structure

First plasma startup scenario development

- For the sake of simplicity and safety, only small parts of PF coils are used in first plasma campaign.
- one limiter configuration (Case I) and one divertor configuration (Case II) with Bt=1.4T, Ip= 200kA, k≈1 are designed in Fig.7.

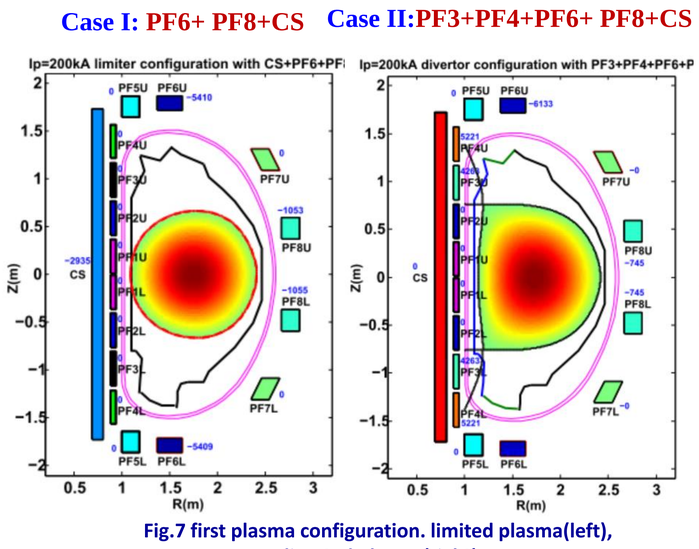

Fig.7 first plasma configuration. limited plasma(left), diverted plasma(right)

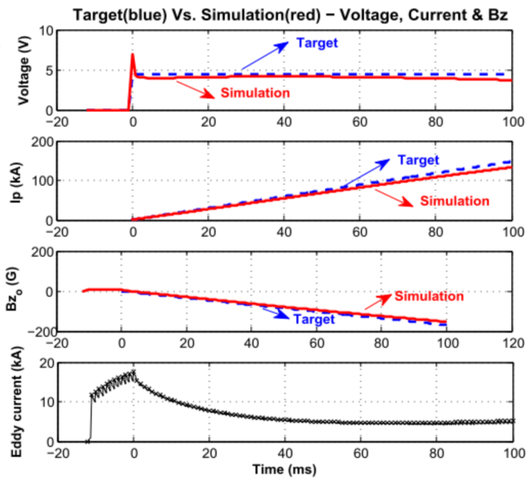

Fig.8 Target and simulation time history based on optimum IM state.

- A simulation comparing target and achievable performance starting from the optimum IM state in Fig.8 shows average voltage 4.1 V, E_{max}= 0.37 V/m.
- PF6 and PF8 are used for field null configuration. Flux (V·s) and B-field pattern expected at plasma breakdown in Fig.9 contains a large region of field null. Field contours expected at 50 ms after breakdown in Fig.10 shows a stabilizing curvature for vertical stability, VDE is not expected.

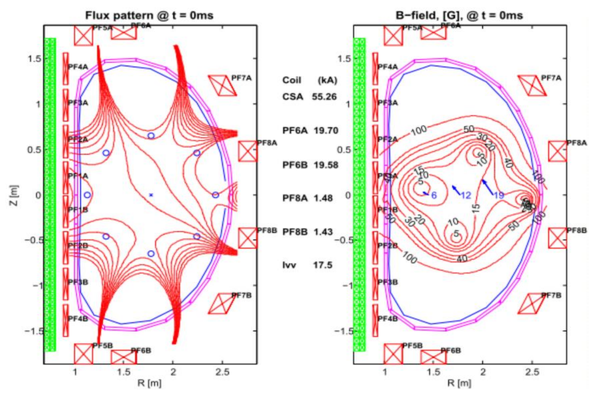

Fig.9 simulated breakdown flux and B-field contours at plasma breakdown, 6~12 G field is shown along midplane

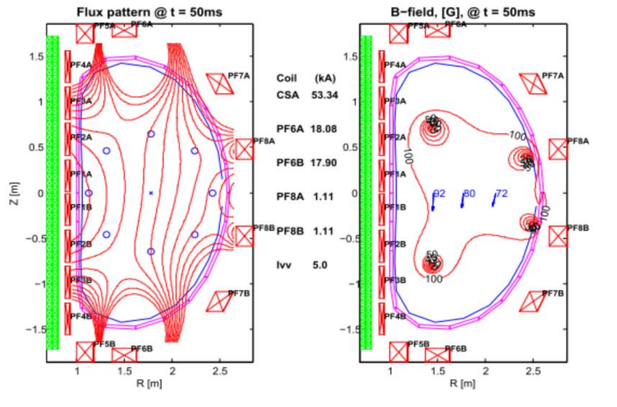

Fig.10 simulated vacuum field contours at t=50ms after breakdown. It contains the correct field curvature needed for vertical stability

- 50 probes signals are linearly combined to form estimates of Rp, Zp by multiplication the coefficients in the rows of E-matrix.
- Ip is from the Rogowski measurement.
- The M-matrix is determined by calculating current or voltage distributions required to produce appropriate fields.

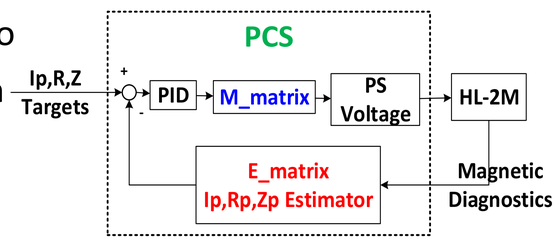

Fig.11 Schematic of PCS circular plasma control algorithm

Summary

- PCS for HL-2M has been developed and control test is on the way .
- First plasma startup scenario development with minimum PF coils and simulation based on optimum IM state has been performed.
- Significant progress has been made for first plasma startup and control.
- PID controllers tuning and engineering test for coil voltage and current control are the main work in the near future.