

Alarm and interlock system in cryogenic system of EAST

LBHu, ZWZhou, M Zhuang, QYZhang and ZGZhu

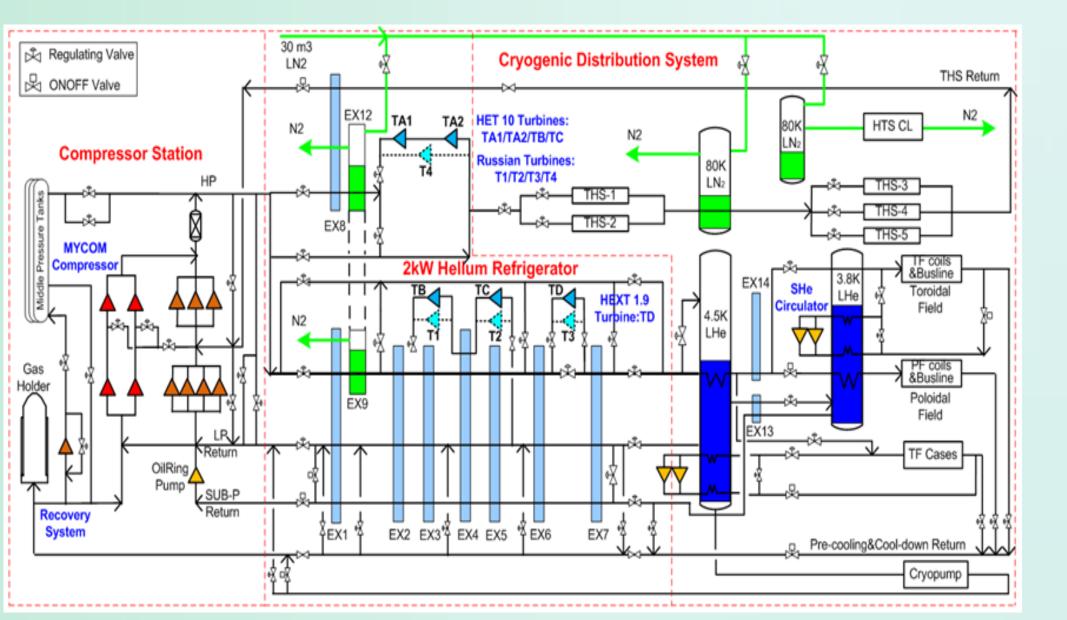
Institute of Plasma Physics, Chinese Academy of Sciences Hefei, 230031, China E-mail: huliangbing@ipp.ac.cn

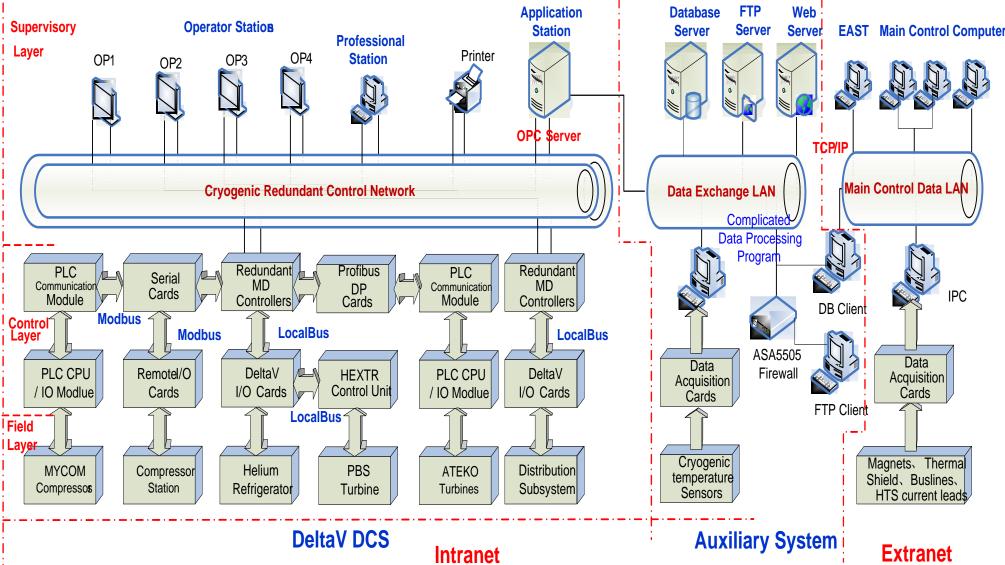


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INTRODUCTION

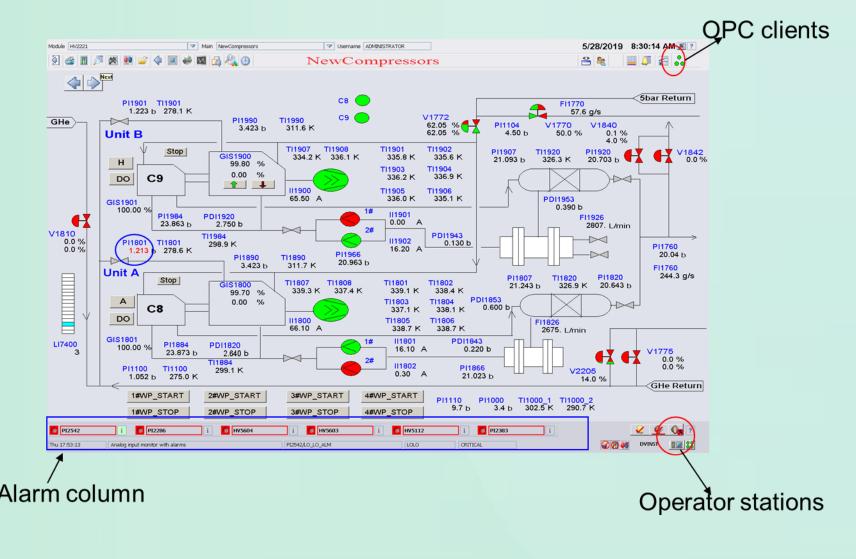
- EAST (Experimental Advanced Superconducting Tokamak) is the first full superconducting experimental Tokamak fusion device which has been carried out fourteen campaigns since its implementation at the end of 2005.
- •The cryogenic system is to cool down the superconducting magnets and relating components. The total cold mass of EAST is about 250 tons.
- ●The basic design capacity of the refrigerator is 1050 W/3.5K +200W/4.5K +13g/s LHe +12~30kW/80K.
- ●EAST cryogenic control system (ECCS) is based on DeltaV DCS of Emerson Corporation.
- •This paper presents the overview of the alarm and interlock system, especially in quench protection in cryogenic system of EAST

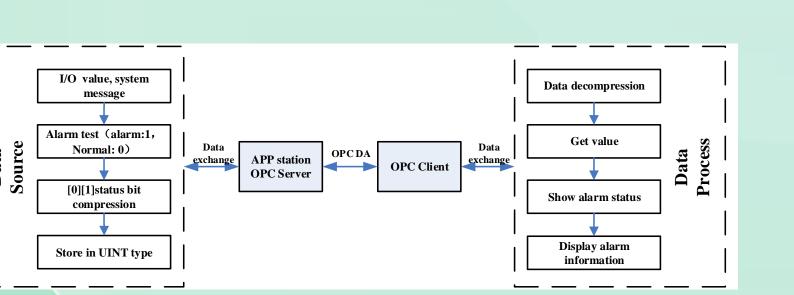


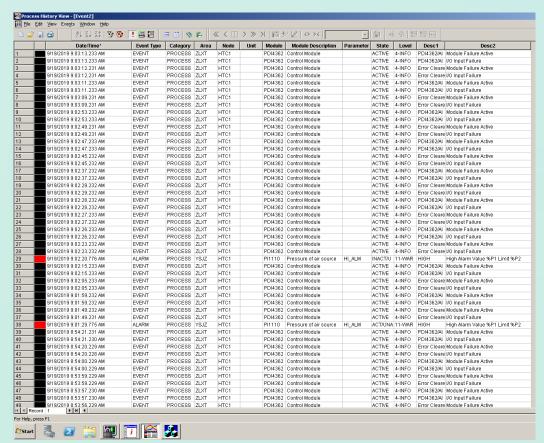


ALARM SYSTEM

- DeltaV provides an extensible processing mechanism to meet the requirements of alarm detection, filtering, prompting and recording.
- •There are about 172 alarm conditions in the cryogenic system.
- The software alarm panel can be customized to make up the shortage of alarm system in DeltaV.
- •The alarm client is based on OLE automation interface and VB.NET language and exchanged data with DeltaV DCS by OPC protocol.







Tag					Value		D-1 f-
8# Comp	PV	9# Comp	PV	STOP Phase Cause Protection	LL	HH Delay [
PI1801	1.21	PI1901	1.22	Suction Pressure of Compressor	0.513 bar	2.513 bar	60
PI1820	20.64	PI1920	20.70	Discharge Pressure of Compressor	1	23.013 bar	0
PI1890 🛑	3.42	PI1990 🛑	3.43	Middle Pressure of Compressor	1	6.013 bar	60
PDI1833 🛑	2.62	PDI1933 🔵	2.76	Oil Pressure Difference	1.513 bar	1	30
TI1884 🛑	299.05	TI1984	298.85	Oil Temperature	1	323 K	0
TI1820 🛑	326.85	TI1920	326.25	Discharge Temperature of Compressor	1	368 K	0
TI1801 🛑	278.55	TI1901 🛑	277.95	Coil Temperature of Main Motor U-1	1	433 K	60
TI1802	337.35	TI1902	336.05	Coil Temperature of Main Motor U-2	1	433 K	60
TI1803	339.15	TI1903	335.75	Coil Temperature of Main Motor V-1	1	433 K	60
TI1804 🛑	338.35	TI1904	335.55	Coil Temperature of Main Motor V-2	1	433 K	60
TI1805	337.05	TI1905	336.15	Coil Temperature of Main Motor W-1	1	433 K	60
	338.05	TI1906	336.85	Coil Temperature of Main Motor W-2	1	433 K	60
TI1806							
TI1806	338.65	TI1907	335.95	Bearing Temperature of Main Motor (Driver)	1	368 K	60

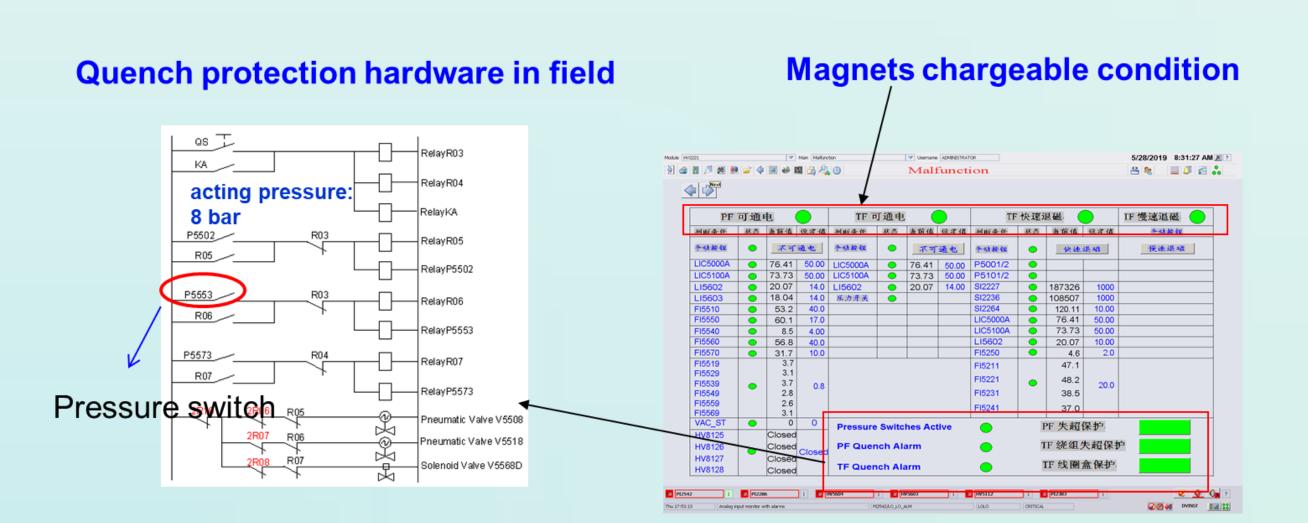
lormal	Alarm ∖		
延温系数重要参数报警 視图(V) 帮助(O)			
1#压机	制冷机系统 透平T1转速低于3krpm	分配系统 引线液氮槽	•
2#压机	● 透平T2转速低于3krpm ●	冷屏液氮槽	•
3#压机	● TD轴承气压力超低停机 🍆	分配阀箱液氢槽	•
4#压机	● 透平T4转速低于3krpm ●	TF氨循环泵	•
5#压机	· 透平油温 ·	TFCASE氨循环泵	•
6#压机	● 制冷机液氮槽 ●	5对HTS温度	
7#压机	一万升杜瓦 🔵	8对HTS温度	
8#压机	● 30立方液氮槽 ●	TF流量	
9#压机	● 真空 ●	PF流量	•
低压压力	- 气源压力 -	Busline流量	•
中压压力低	■ 其他 气柜高度	油环泵	•
高压压力	通电状态 ●	磁体预冷温差	•
水压	● TF退磁反馈 ●	冷屏预冷温差	•
中压	压力低 透平T1转速 Qual	ty:Good 2019-9-19 9:	08-14

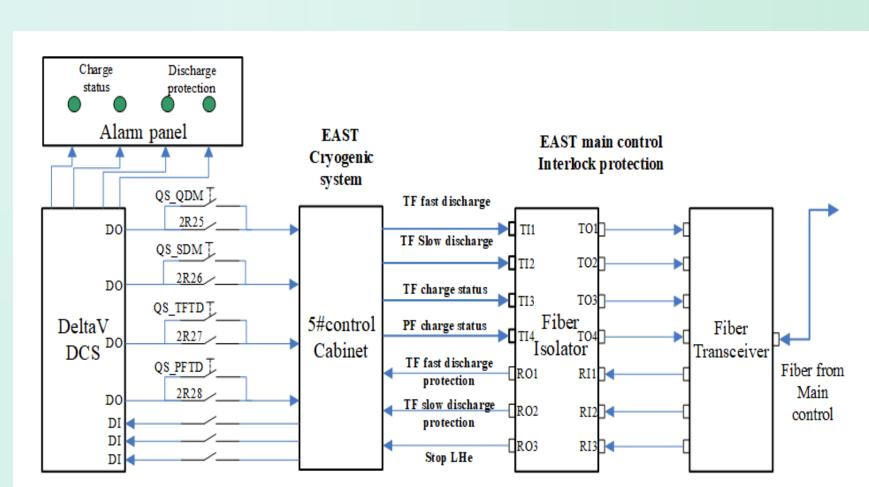
Alarm information

D	Protec	B	A	STOP Phase Cause Protection	Value	PV	Reaction Time [s]	ERROR Code
0	0	0	0	Normal State			-	0
0	0	0	х	P2 Cooling Water TI2563	> 313 K	292.58	30	1
0	0	х	0	P3 HEXT1.9 Speed Sensor Resistance	R < 50 or R > 1k	-	0	2
0	0	х	х	P3 HEXT1.9 Speed Sensor Resistance	or U < 0.8 Upk	-	0	3
0	х	0	0	P4 HEXT 1.9 Brake Resistance	R < 5 or R < 30	-	0	4
0	х	0	х	P4 HEXT 1.9 Brake Resistance	K < 50 K < 50	-	0	5
0	х	х	0	P5 HEXT 1.9 Under speed SI2264	< 79998 rpm	120.11	10	6
0	х	х	х	P5 HEXT 1.9 Under speed	< 79998 rpm	120.11	10	7
х	0	0	0	P6 HEXT 1.9 Over speed	> 180000 rpm	120.11	0	8
х	0	0	х	P6 HEXT 1.9 Over speed	> 180000 rpm	120.11	0	9
х	0	х	0	P7 Bearing Gas Pressure PI2292	< 7 bar	8.04	30	Α
x	0	х	Х	P8 HEXT 1.9 Inner Pressure PI2264	> 12.97bar (design)	8.05	1	b
х	х	0	0	P8 HEXT 1.9 Inner Pressure	> 12.97bar (design)	8.05	1	С
х	х	0	х	P9 Water Flow	Disconnected	Connected	30	d

INTERLOCK SYSTEM

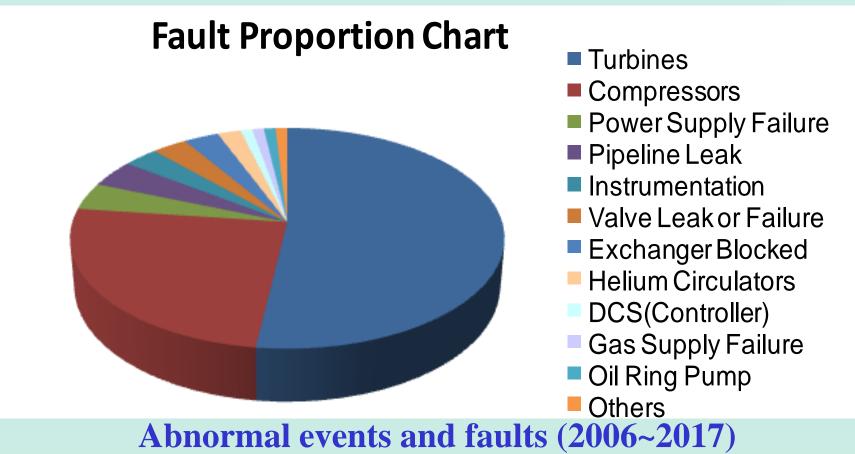
- There are about 35 interlocks conditions to protect the compressors, turbine expanders, 10000 liter Dewar and superconductor magnets.
- •The high real-time protection signal directly sets the hardware prior protection circuit of field devices to shorten the interlock control response time and insure the security of equipment.
- The backup software protection strategy will be triggered when there is a failure in the hardware protection circuit. This protection measure is used such as the quench protection and turbine safety interlock control.
- •For the protection signal which is important but the real-time requirement is not high, the security response mode of software configuration and hardware interlock circuit is adopted. When the protection logic of DCS failed to action, the hardware circuit will directly send the interlock protection signal. This method is used to the interlock control between cryogenic system and main control system of EAST.

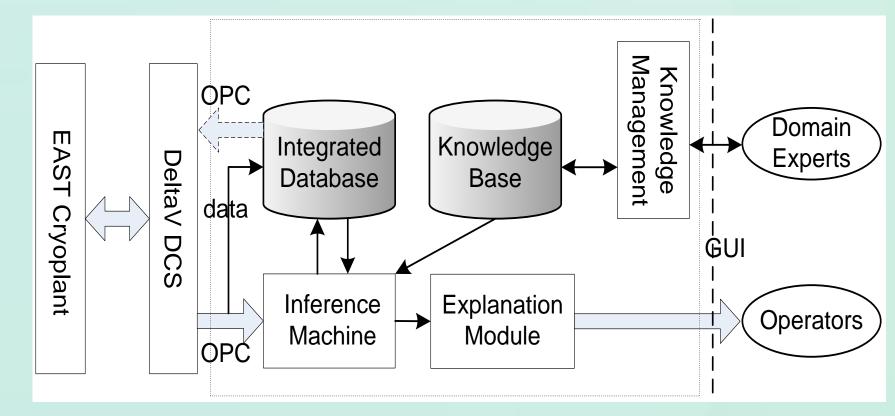




OPERATION PERFORMANCE

- The fault modes of the EAST cryogenic system was analyzed. The fault rate is 5% before the system upgrade. The turbine and compressor fault stop caused by mechanical failure and can not be restated in short time again.
- EAST cryogenic system was upgraded with new helium screw compressors and new dynamic gas bearing helium turbines. The fault stop of turbines and compressors never happened after system upgrade in 2016.
- •A real-time fault diagnosis expert system was developed to facilitate dealing with abnormal situations for improving the efficiency and reliability of the system.





The structure of the real-time fault diagnosis expert system

CONCLUSION

- The alarm and interlock system has been verified the long term stability, reliability and higher automation.
- The fault modes of the system as well as the corresponding effects and criticality have been analyzed for improving the reliability of the EAST cryogenic system.
- The typical fault of cryogenic system and the emergency control strategy will be simulated based on EcosimPro to enhance the reliability of the cryogenic system and automatic processing ability in fault state.