# HIGH AVAILABILITY SOFTWARE ARCHITECTURE OF C-ADS CONTROL SYSTEM

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### Abstract

The control system of Accelerator Driven Sub-critical System (ADS) should be a high-availability (HA) system with fault tolerant architecture, due to the potential utilizations of the ADS, such as separating and transmuting irradiated nuclear fuel. This paper discusses the HA software architecture of ADS control system which mainly composed by four softwares, which are 1) low floor communication and control system---EPICS [1], 2) hierarchal programming framework of the accelerator —XAL [2], 3) monitoring and operating large scale control systems—Control System Studio (CSS) [1], 4) data storage and service infrastructure—HA database and server cluster. In addition, the recent development of ADS control system is briefly introduced in this paper.

### **INTRODUCTION**

The ADS has been universally regarded as the most effective approach to dispose the long-lived nuclear wasted [3]. In 2011, the Chinese Academy of Sciences launched the "Strategic Priority Research Program" named "Future Advanced Nuclear Fission Energy". This program has two sub-programs, and the ADS Project is one of them.

### SOFTWARE ARCHITECTURE

Overall relationship of the softwares which included in the HA software architecture is shown in Fig. 1. Communication with the diagnostics and beamline devices is through the EPICS control system, or more specifically via the Java Channel Access (JCA) interface. CSS projects and XAL applications run on the Linux server cluster. They can read data from the HA database or write data to it.

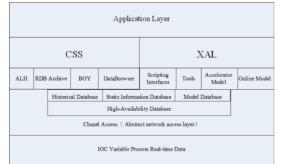


Figure 1: HA software architecture of ADS Control System.

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## EPICS

EPICS is a software environment originally written jointly by Los Alamos National Laboratory and Argonne National Laboratory. It is used to develop and implement distributed soft real-time control systems to operate devices such as particle accelerators, telescopes and other large experiments. Now, over 100 large scientific facilities throughout the world use the EPICS, such as NSRL, BEPCII and SSRF. ADS also uses EPICS as the underlying control system to communicate with accelerator hardware.

### XAL

XAL is designed to be a heaton applications for beam for developing accelerator physics applications for beam XAL is designed to be a flexible application framework commissioning [2]. XAL has advanced design concept and many features that users expect from modern applications. It has been adopted by many international accelerator laboratories and adopting it for ADS is a key subject in the long term. Use of this framework, the control system operators can write applications that can be applied to the accelerator. Virtual Accelerator is an important application in XAL. With the Virtual Accelerator, it is possible for an operator to judge whether setting parameters would be justified or not, examine the control system of the machine and practice the commissioning without a beam. The screenshot of ADS Virtual Accelerator is shown in the Fig. 2. ADS has some specific information, such as the bunchers in MEBT1 and RF cavities in CM1 use the new attribute ETL instead of the separate properties—the longitudinal electric field(E), the transit time factor (T) and the gap length (L). So proper modification is needed in order to better suit ADS online modeling purpose.

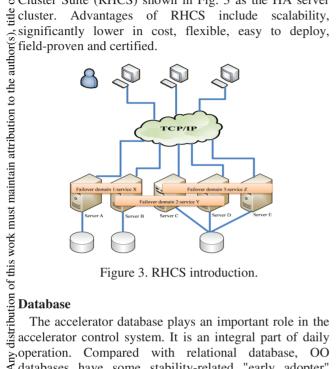
Virtual Accelerator - (MEBT1-CM1) - Untitled.va* File Edit Accelerator Mode View Window Help							
File Edit Ac	celerator Mode	View Wind	low Help				
Probe File	Probe Editor	Set Noise	Start VA	Stop VA			
ilter							
Node		Readback PV			Readback	Setpoint PV	Setpoint
MEBT1_Mag:QH01		MEBT1_Mag:QH01:8				MEBT1_Mag:P5_QH01:B_Set	30
MEBT1_Mag:QV02		MEBT1_Mag:QV02:B			MEBT1_Mag:PS_QV02:B_Set	23.30	
MEBT1_RFBnch01		MEBT1_LLRF:FCM1:cavPhaseAvg		haseAug	-90.093307	MEBT1_LLRF:FCM1:CtlPhaseSet	-90.0933
MEBT1_RFBnch01:Rg01		MEBT1_LLRF:FCM1:cavETL		0.081490995	MEBT 1_LLRF FCM 1: CIIET LSet	0.08149095	
MEBT1_Mag OH03		MEBT1_Mag:QH03:B		13.6887	MEBT1_Mag:PS_QH03:B_Set	13.68	
MEBT1_Mag QV04		MEBT1_Mag:QV04:B		16.8444	MEBT1_Mag:PS_QV04:B_Set	16.84	
MEBT1_RFBnch02		MEBT1_LLRF:FCM2:cavPhaseAug		haseAug	-90.060978	MEBT1_LLRF:FCM2:CtlPhaseSet	-90.06093
MEBT1_RFBnch02:Rg01		MEBT1_LLRF:FCM2:cavETL		ri,	0.087055899	MEBT1_LLRF:FCM2:CtIETLSet	0.0870558
MEBT 1_Mag: OH05		MEBT1_Mag:QH05:8			14.0463	MEBT 1_Mag: PS_QH05:8_Set	14.04
MEBT 1_Mag 0V06		MEBT1_Mag:0V06:B				MEBT1_Mag PS_0V06:B_Set	15.66
CM1_RFSCLCavtv01		CM1_LLRF:FCM1:cavPhaseAvg		DVA 93	-39.98517	CM1_ULRF:FCM1:CtlPhaseSet	-39.985
CM1_RF:SCLCavhy01:Rg01		CM1.LLRF:FCM1:cavETL				CM1_LLRF:FCM1:CtIETLSet	0.27776
CM1_MagSOLE01		CM1_Mag/SOLE01:8				CM1_Mag PS_SOLE01:8_Set	-0.7299
CM1_RFSCLCavtv02		CM1.LLRF:FCM2:cavPhaseAvg		seAvg	-37.98517	CM1_ULRF:FCM2:CtlPhaseSet	-37.9851
CM1_RF:SCLCavev02:Rg01		CM1.LLRF:FCM2:cavETL			CM1.LLRF.FCM2:CIIETLSet	0.321928	
CM1_Mag SOLE02		CM1.Mag/SOLE02:8			-0.755629	CM1_Mag PS_SOLE02:8_Set	-0.7556
CM1_RF:SCLCavhy03		CM1.LLRF:FCM3:cavPhaseAvg		-36.988708	CM1_ULRF:FCM3:CtlPhaseSet	-36.98870	
CM1.RF:SCLCavtrv03:Rd01		CM1.LLRF:FCM3:cavETL		0.37006249		0.3700624	
CM1.MagSOLE03		CM1.Mag/SOLE03:8		-0.784701	CM1_Mag PS_SOLE03:8_Set	-0.7847	
CM1_RF:SCLCavity04		CM1.LLRF:FCM4:cavPhaseAvg		-34.990133		-34.9901	
	SCLCavtv04:R001 CM1.LLRF.FCM4:cavETL			0.4415414		0.44154	
CM1.Mag SOLE	ag SOLE04 CM1.Mag SOLE04:8			-0.819133		-0.8191	
CM1_RF:SCLCa			ce.Avg		CM1_LLRF:FCM5:CtlPhaseSet	-32.9914	
	F:SCLCavItv05:R001 CM1.LLRF:FCM5:cavETL				CM1_LLRF.FCM5_CtIETLSet	0.534902	
CM1.Mag.SOLE05		CM1.Mag.SOLE05:8				CM1. Mag.PS. SOLE05 B. Set	-0.85751
CM1_RF:SCLCavity06		CM1_LLRF_FCM6.cavPhaseAvg			CM1_LLRF:FCM6:CtIPhaseSet	-29.9926	
CM1 RF:SCLCavtv06:Rp01		CM1 LLRF:FCM6:cavETL				CM1 LLRF.FCM6.CIIETLSet	0.6828866

Figure 2: ADS virtual accelerator.

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## HA Database and Server Cluster

HA Database an HA Server Cluster HA server cluster HA server clusters provide continuous availability of  $\frac{1}{2}$  services by eliminating single points of failure and by failing over services from one cluster node to another in gase a node becomes inoperative [4]. ADS uses RedHat ៉ Cluster Suite (RHCS) shown in Fig. 3 as the HA server  $\frac{2}{2}$  cluster. Advantages of RHCS include scalability,



operation. Compared with relational database, OO databases have some stability-related "early adopter"  $\div$  problems. Among the large relational database a management system product, MySQL is extremely easy O to use and is the world's most popular open source database. These factors led us choose MySQL as the ADS licence accelerator database.

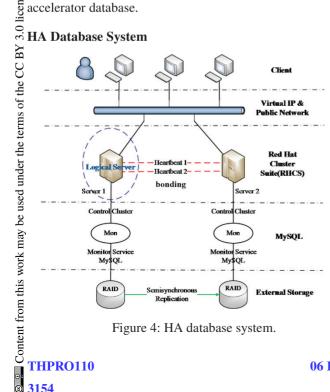


Figure 4: HA database system.

The schematic diagram of HA database system is shown in Fig. 4. ADS uses fencing, bonding, Mon and MySQL replication as the HA database solution. Fencing shown in Fig. 5 is a technology used to remove a cluster member from an active cluster, as determined by loss of communication with the cluster. Split-brain condition [5] is avoided to a certain extent by using the fencing technique. RHCS has more fencing technologies than other HA server clusters, such as Veritas Foundation Suite or Oracle Clusterware. The Linux bonding driver provides a method of combining multiple network interfaces in parallel to increase the reliability of the system. It is the best way to provide redundancy for the heartbeat. 'Mon' is a general-purpose scheduler and alert management tool used for monitoring service availability and triggering alerts upon failure detection [6]. The HA database system uses 'Mon' to monitor the MySQL service. If the MySQL service in master server fails, 'Mon' will instruct the RHCS to fail over the service from the master server to the slave server. The HA database system uses redundant arrays of inexpensive disks (RAID) as the external storage and uses MySQL replication for the purpose of backup. The most important benefit of using replication is that you can perform database backups using a slave server without disturbing the master. The master continues to process updates while the backup is being made.

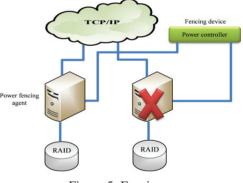


Figure 5: Fencing.

### CSS

CSS is based on the Eclipse Rich Client Platform (RCP) and is a collection of useful tools: RDB Archive, "Best Ever Alarm System Toolkit" (BEAST), "Best OPI, Yet" -BOY, as well as some control system diagnostic tools. Compared With the old GUI tools: EDM and MEDM, the Operator Interface (OPI) of CSS applications is elegant, simple, easy to operate and common look-and-feel. Figure 6 below shows the screenshot of the MEBT1 control system. The middle part of the control system interface shows the devices in the MEBT1. If the users click the magnet or bunch icon, the corresponding setting interface will show in the lower part. The users can adjust parameters for the magnet or bunch. The value of SigmaX and SigmaY shown in the upper part will change according to the current configuration.

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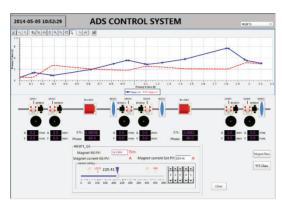


Figure 6: GUI of the ADS Control System.

### Archive

ADS uses Relational Database Channel Archiver (RDB Archive) to archive operational data. As you can see from the left part of Fig. 7, the data was lost during the fail-over time for the slave node to take over the MySQL service. Proper modification is needed in order to better suit ADS data requirement. The flowchart of the new RDB Archive is shown in Fig. 8.

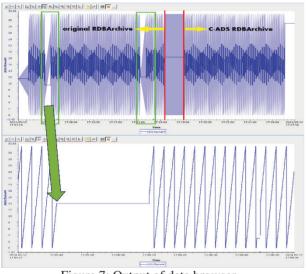


Figure 7: Output of data browser.

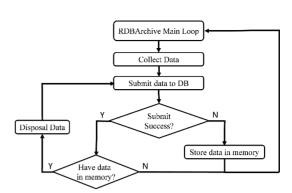


Figure 8: Flowchart of C-ADS RDB archive.

### **CONCLUSION**

The ADS will benefit from the HA software architecture which mainly composed by EPICS, XAL, CSS and HA database and server cluster. We need to intensive study XAL, CSS, MySQL Replication and RHCS, keep a close watch on the new technology, strengthen the international exchanges and cooperation, set up the world-class accelerator control system.

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