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DATA ACQUISITION AND ARCHIVING SYSTEM FOR HEPS RF SYSTEM BASED ON ARCHIVER APPLIANCE

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Abstract

High Energy Photon Source is a 6 GeV fourth-generation synchrotron light source currently under construction in Huairou, Beijing. It consists of 13 Radio Frequency (RF) stations. Each RF station consists of a solid-state amplifier, an RF cavity, a LLRF controller, an interlock controller, etc. To monitor the status of all 13 RF stations, approximately 60,000 process variables need to be acquired and archived, which shall require 600 terabytes of hard disk space for 3-year data storage. For a large number of historical data, the conventional RDB Channel Archiver does not perform well in data retrieval. Therefore the EPICS Archiver Appliance is applied and its performance was evaluated. The results indicate that the new archiving system is reliable and convenient for management and maintenance. Compared with the RDB Channel Archiver, the Archiver Appliance has the advantages of clusterable design, high read/write performance and ease for expansion. The architecture of the data acquisition and archiving system is presented in this paper.

INTRODUCTION

High Energy Photon Source (HEPS) is a 6 GeV diffraction-limited synchrotron light source with a kilometer-scale circumference currently under construction in Huairou, Beijing [1,2]. It comprises a 500 MeV electron linear accelerator, a booster ring, a storage ring, and multiple beamlines. The electron beam is firstly accelerated by the linear accelerator before being injected into the booster ring. Before injecting into the storage ring, the beam energy is further ramped up to 6 GeV.

Five 166.6 MHz superconducting RF (SRF) cavities will be installed in the storage ring as main accelerating cavities accompanied by two 499.8 MHz SRF cavities as third harmonic cavities [3,4]. Each cavity will be driven by a 260 kW solid-state power source. Six normal-conducting cavities will be installed in the booster ring with each driven by a 100 kW solid-state power source. The layout of the radio frequency (RF) system is shown in Fig. 1. Its main beam parameters are listed in Table 1. To monitor the status of all 13 RF stations, approximately 60,000 process variables need to be acquired and archived, which shall require 600 terabytes of hard disk space for 3-year data storage.

At present, the data of each RF station which includes the status and the operating parameters of the key equipment were collected by the Experimental Physics and Industrial Control Systems (EPICS) Input/Output Controller (IOC). It is then stored via the EPICS RDB Channel Archiver. However, with the increased amount of data, the limitation of RDB Channel Archiver gradually emerged, such as the archiver can only be installed and run on a single machine, so it cannot be quickly expanded to improve its performance. In addition, the RDB channel archiver developed in the lab is no longer updated and supported, etc. Therefore the EPICS Archiver Appliance [5] was adopted. The architecture of the data acquisition and archiving system is presented in this paper.

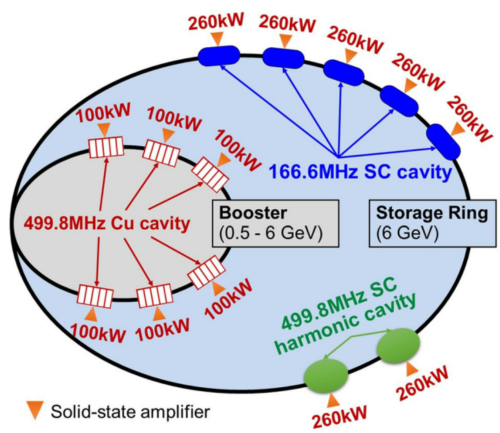

Figure 1: Layout of the HEPS RF system.

Table 1: Main Parameters of HEPS

Parameter	Value	Unit
Booster RF		
Circumference	454.066	m
Beam energy (injection)	0.5	GeV
Beam energy (extraction)	6	GeV
Beam current	13	mA
Energy loss per turn	4.02	MeV
Total RF voltage	2 to 8	MV
Storage-ring RF		
Circumference	1360.4	m
Beam energy	6	GeV
Beam current	200	mA
Energy loss per turn (w/ IDs)	4.14	MV
Total beam power	850	kW
Fundamental RF frequency	166.6	MHz
Total RF voltage	5.16	MV
3rd harmonic RF frequency	499.8	MHz

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ARCHITECTURE

The EPICS Archiver Appliance is deployed by using an appliance model [6]. An installation is a cluster of appliances. There are multiple storage stages and multiple processes in each appliance (see Fig. 2).

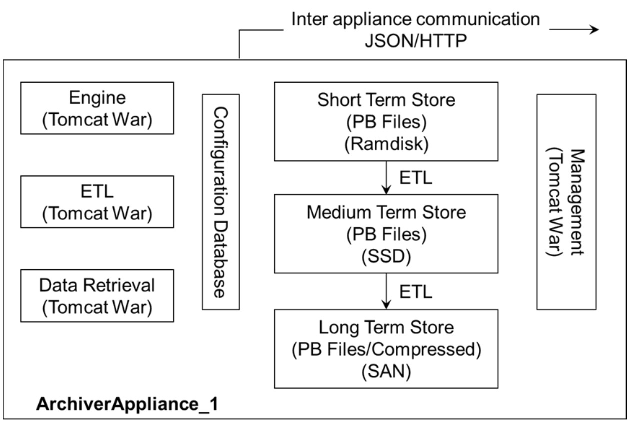

Figure 2: Architecture of an appliance.

The functions of its main modules are listed as follows:

1) Storage module

- Short Term Store (STS): This module stores data within a few hours. Because it directly gets the data from the IOC of each station and it needs high access speed. A RAM disk is used.
- Medium Term Store (MTS): This module stores data within a few days, which can be saved on the hard disk of the computer. To improve performance, the solid state drive is used as a storage medium.
- Long Term Store (LTS): This module stores data for the rest of the time. Due to the large amount of data stored, and to ensure the scalability of data storage space, a network storage server is used as a storage medium.

2) Data processing module

- Engine: This module is based on the CS-Studio engine and it establishes an EPICS channel access monitor for each PV in the device. The data is written into the STS.
- Extract Transform and Load (ETL): This module moves data from the STS to the MTS and from the MTS to the LTS.
- Data extraction module (Retrieval): The main function is to obtain data that meets the requirements from the storage space according to the data request.
- Application interface management module (Management): This module executes business logic, manages the other three components, and saves the state of the runtime.

Devices and modules communicate in a variety of ways, including JSON/HTTP. The archived configuration of each device is usually stored in a MySQL database.

DEPLOYMENTS

As is shown in Fig. 3, six Dell PowerEdge R750s were used to build the HEPS RF local database. Each server has 2 CPUs (Intel Xeon Gold 5318Y), 256 GB or 512 GB memory, 4×2 T SSDs, 8×16 T SAS HDDs, 1×4-port 1 GbE BaseT LAN and 1×4-port Intel X710 10 GbE SFP + LAN.

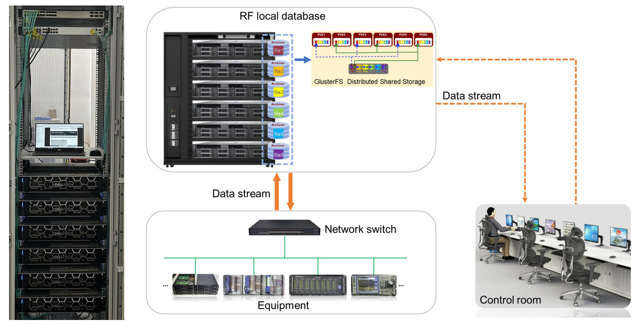

Figure 3: Architecture of the HEPS RF local database.

Proxmox VE (PVE) is a platform to run virtual machines (VMs) and containers. It is based on Debian Linux and is completely open-source. Because the PVE High Availability (HA) Cluster which is based on proven Linux HA technologies can provide stable and reliable HA services, we select PVE as the server's operating system (OS). As is shown in Fig. 4, six servers form a highly available cluster with two separate networks (1 GbE and 10 GbE). The 1 GbE network is used for cluster communication and the 10 GbE network is used as a dedicated network for migration. In addition, all management tasks can be done by using the web-based management interface, and even novice users can set up and install PVE in minutes.

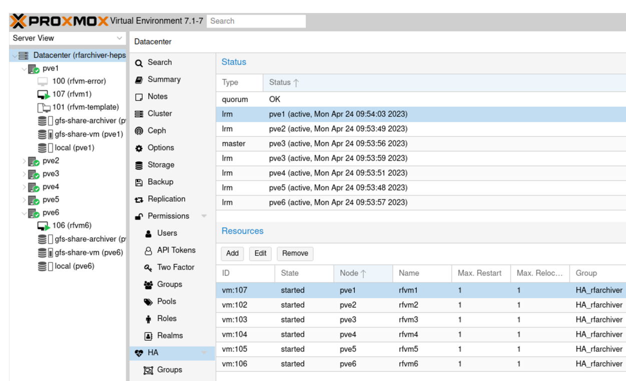

Figure 4: HA group.

Create a Debian 10 virtual machine on each PVE server. Setting the correct OS allows PVE to optimize some low-level parameters. Figure 5 shows the parameter configuration of each VM. VM images can be stored on one or more local storage, or shared storage such as NFS and SAN. We use GlusterFS distributed storage to archive VMs and data (see Fig. 6), which guarantees live migration of running VMs without downtime, and all nodes in the cluster have direct access to the VM disk image.

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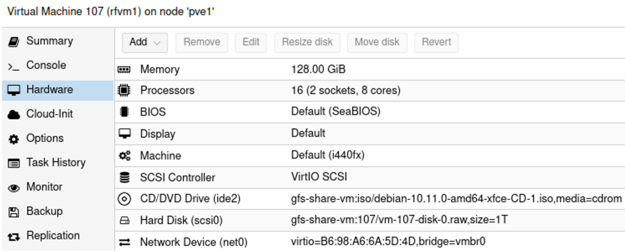

Figure 5: Parameter configuration of each VM.

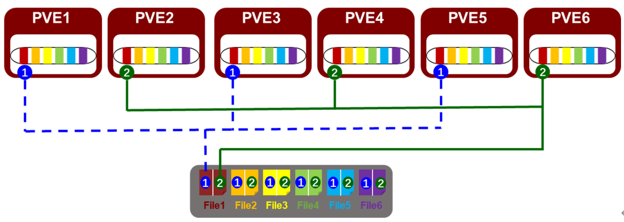

Figure 6: GlusterFS distributed storage.

Install one EPICS Archiver Appliance per VM. A key feature of the EPICS Archiver Appliance is the ability to cluster devices for high performance. The HEPS RF local database was deployed on a cluster of 6 EPICS Archiver Appliances. The appliance *.xml* file can be used to configure access URLs and clusters.

The EPICS Archiver Appliance comes with plugins for the ArchiveViewer and the CS-Studio [7] data browser. We are also currently developing the HTML5 viewer for archiver data. The web front-end interface we are currently using is shown in Fig 7.

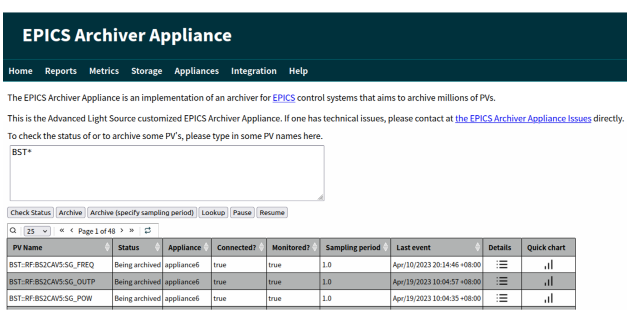

Figure 7: Home page of the EPICS Archiver Appliance.

PRACTICAL APPLICATION

The system has monitored and archived 1194 PVs of one solid state amplifier for 72 hours, the sampling mode was monitored, and the cache space was configured according to the space requirements of a 1 s period. Figure 8 shows the historical data trend curve displayed on the interface.

We also tested the VM migration. The result shows when the server was manually restarted or shut down, all VMs were not migrated, and the VM status changed from started to freeze. However, when the server was interrupted abnormally, such as a network failure or a sudden power outage of

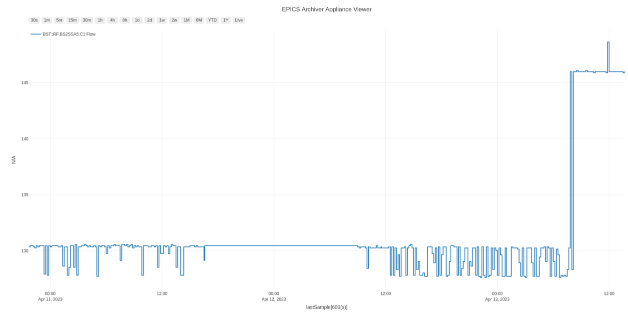
Figure 8: Display page for realtime data.

the server, the VM was migrated to another normal operating server.

Compared with the RDB Channel Archiver, the Archiver Appliance has the advantages of clusterable design, high read/write performance and ease for expansion.

CONCLUSION

A data archiving system was developed for the HEPS booster, and the status of the solid state amplifiers on an RF station was monitored and archived for 72 hours. At present, this system has completed the development of basic functions, and we will continue to optimize the user interface and improve various functions, such as real-time monitoring, real-time data analysis, etc.

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