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STATUS UPDATE FOR THE HIT ACCELERATOR CONTROL SYSTEM

J. M. Mosthaf†, A. Peters, T. Haberer, K. Höppner, S. Hanke
Accelerator Control Systems, Heidelberg Ion-Beam Therapie Centre, Heidelberg, Germany

Abstract

Changes in the accelerator beamline of the Heidelberg Ionbeam Therapy-Center (HIT) and in virtualization hardware and software as well as demands for more redundancy and performance prompted an overhaul of the accelerator control system (ACS) and a new approach to the hardware base.

The addition of a third ion source necessitated an expansion of the Virtual Accelerator (VAcc) structure both in the database and the Device Control Units (DCU) software. To increase redundancy and system performance, new virtualization servers and storage systems were used and the ACS database needed to be revised. To take advantage of newer hardware and operating systems, all server programs and GUIs were converted to a 64 bit base. As a quality of life and security improvement, the download and flash functionality of the ACS were updated to enhance performance and security checks.

The new virtualization host server and infrastructure hardware in conjunction with the 64 bit update and ensuing efficiency increases have resulted in a safer and significantly faster ACS with higher redundancy in case of hardware failure.

INTRODUCTION

The Heidelberg Ion Therapy Centre (HIT) is a dedicated hadron accelerator facility for radio-therapeutical treatment of tumour patients. The two horizontally fixed treatment places, the 360° gantry, as well as the experimental area can be served with proton and carbon beams with qualified beam parameters (MEFI – seeTable 1), helium is available for the experimental area and oxygen is being tested.

The achieved energy range of 88-430 MeV/u for carbon ions and 48-221 MeV/u for protons and helium is sufficient to reach a penetration depth of 20-300 mm in water.

Table 1: MEFI Beam Parameters for Main Ion Types

Parameter	Steps	Protons	Carbon	Helium
Energy	255	48 – 221 MeV/u	88 - 430 MeV/u	50 - 220 MeV/u
Focus	4 (6)	8 - 20 mm	4 - 12 mm	2 - 9 mm
Intensity	10 (15)	$4 \cdot 10^8$ – $1 \cdot 10^{10}$ 1/s	$1 \cdot 10^7$ – $1 \cdot 10^8$ 1/s	$1 \cdot 10^7 - 1 \cdot 10^9$ 1/s

CHANGES IN THE ACCELERATOR

In 2015 a third ion source was constructed and integrated into the beamline [1]. This ion source is used to supply helium ions into the accelerator and necessitated an addition of five new therapy Vaccs (see Figs. 1 and 2). This in turn changed the data structure for therapy data in the device control units (DCU) and in the database.

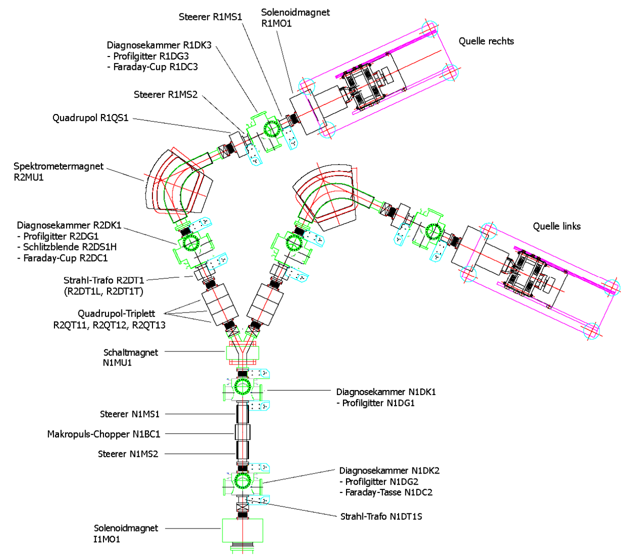

Figure 1: Former LEBT with two ion sources.

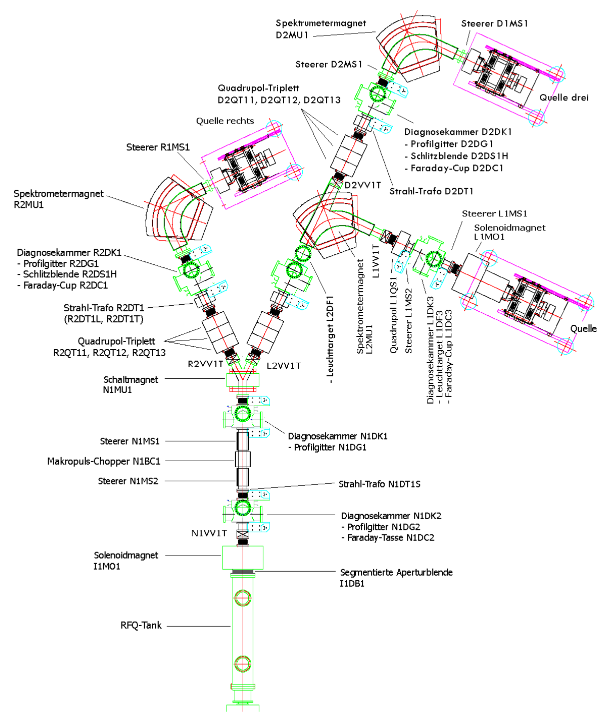

Figure 2: New LEBT with three ion sources.

Changes in Therapy VAccs and MEFI Data

A "virtual accelerator" or VAcc defines a beamline from one of the ion sources to one of the target rooms. It contains

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all of the devices needed to thread the beam from extraction to target and can further be defined by all the possible MEFI parameters – **M**ass of the ion (H, He, C or O), **E**nergy (1-255), **F**ocus (1-4) and **I**ntensity (1-10). With two ion sources and 5 target rooms (including beam dump), we needed 10 VAccs to define each beamline from ion source to target. The third ion source adds another 5 VAccs to that roster. (see Table 2).

As every device contains control data for every VAcc and the MEFI it needs, the data structure containing all possible control values for all possible MEFI combinations must be expanded to accommodate the 5 new VAccs.

Table 2: New therapy VAccs

Ion Source	Horiz. Rooms	Gantry	Experiment Room	Beam Dump
QL(carbon)	Vacc 1-2	VAcc 3	VAcc 4	VAcc 5
QR(proton)	VAcc 6-7	VAcc 8	VAcc 9	VAcc 10
QD(helium)	VAcc 11-12	VAcc 13	VAcc 14	VAcc 15

This necessitated a change in DCU software and in the database, where all the relevant data for all the devices is stored. As each device contains two separate versions of MEFI data - flash storage for therapy data and normal RAM storage for experiment data – and a third version in the accelerator database, called “Offline RAM” for machine tests etc. is used, this increases data handled in each operation considerably. Downloads to devices, Flash to devices, data interpolations for accelerator conditioning… was slowed down. A complete download to all devices took up to 20 minutes to complete with all necessary integrity and checksum tests.

CHANGES IN THE ACS

Software Update and Virtualization

The ACS Software was upgraded to run on 64-bit libraries and use the 64-bit Oracle client. This allows the server applications and client GUIs to use more memory and improves performance significantly.

Several quality of life improvements to GUIs and server applications made working with therapy data safer and easier. Because of frequent user mistakes, the most important of those is the new Download/Flash GUI (see Fig. 3) which automatically verifies downloads and flashes checksums and makes sure that no corrupt data gets written to devices and stops the execution of beam plans. It also enables an “undo flash” function and backup and restore of flash data. Additionally, the device replacement functionality was grouped into a single command, which ensures, that all firmware and software versions are up to date and correct MEFI data is downloaded and flashed to the replaced device.

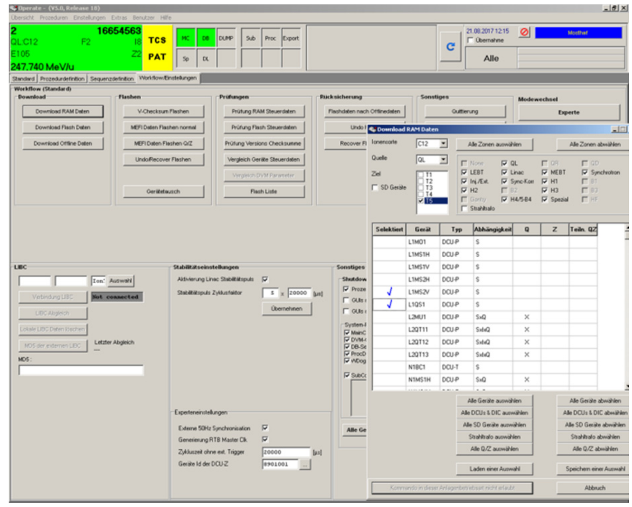

Figure 3: Download/Flash GUI with selection widget.

All server and gateway applications were also modified to work in virtual machines and hardware requirements were modified to work over Ethernet. SPS embedded systems and serial-to-Ethernet boxes were used to provide communication to the virtual gateways computers.

Server Upgrades

Defective SAS controller drivers for VMware ESXI caused a failure in our virtualization servers and prompted an upgrade to a more redundant and secure hardware setup. As the ACS was set to move to complete virtualization, we moved from blade servers to two identical dedicated HP Proliant DL380gen9 virtualization host servers running ESXI 6

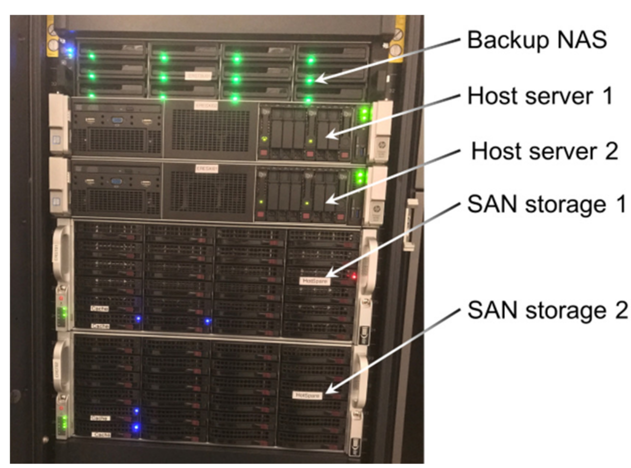

Figure 4: ACS rack with servers, storage and NAS box for backups.

Storage was moved to a mirrored Eurostor RAID SAN with a dedicated 10GbE network providing iSCSI volumes for the cluster (see Fig. 4). A dedicated 10 GB/s storage network with redundant switches and routes was implemented to make access to storage fast and resistant to failure.

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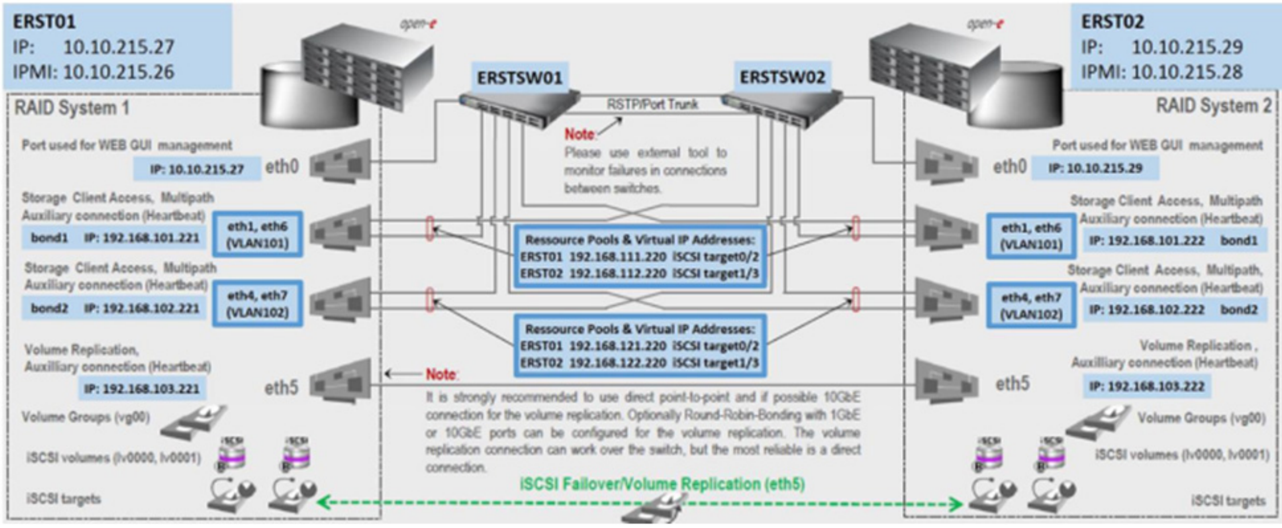

Figure 5: Concept for the ACS server storage iSCSI network.

For backup a Synology NAS box is used with Veeam backup of the virtualization environment (Fig. 5). The ACS servers run in a VMware cluster on both servers and each host is capable of running the complete ACS without undue system load.

CONCLUSIONS

With the new server hardware, we now have a redundant setup with two identical virtualization hosts and a mirrored SAN for storage with failover procedures in place. Both hosts are clustered in vSphere and are capable of running all of the ACS servers with automatic failovers of virtual machines.

The more powerful host servers and database structure overhaul as well as a dedicated 10GB network between all ACS servers improved the system performance significantly. A complete therapy data download to all devices now takes ~5 minutes compared to ~15 minutes on the former blade system.

The GUI upgrades provide a safer and faster download and flash environment and numerous improvements to daily handling of the system.

REFERENCES

[1] T.W. Winkelmann, A.B. Büchel, R. Cee, A. Gaffron, Th. Haberer, J.M. Mosthaf, B. Naas, A. Peters, J. Schreiner, "Integration of a Third Ion Source for Heavy Ion Radiotherapy at HIT", Sydney, Australia, 2012. in *Proc. ECRIS'12*, paper TUPP03.