THE ANKA CONTROL SYSTEM: ON A PATH TO THE FUTURE

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Abstract

The machine control system of the synchrotron radiation source ANKA at Karlsruhe Institute of Technology (KIT) is migrating from dedicated I/O microcontroller boards that utilise the LonWorks field bus and are visualised with the ACS Corba based control system to Ethernet TCP/IP devices with an EPICS server layer and visualisation by Control System Studio (CSS). This migration is driven by the need to replace ageing hardware, and in order to move away from the outdated microcontroller's embedded LonWorks bus. Approximately 500 physical devices, such as power supplies, vacuum pumps etc, will need to be replaced (or have their I/O hardware changed) and be integrated to the new EPICS/CSS control system. In this paper we report on the technology choices and discuss justifications of those choices, the progress of migration, and how such a task can be achieved in a transparent way with a fully user operational machine. We also report on the benefits reaped from using EPICS, CSS and BEAST alarming.

INTRODUCTION

ANKA is an electron synchrotron radiation light source located in Karlsruhe, Germany. The storage ring is generally operated at an energy of 2.5GeV with a typical beam current of 200 mA and a life time of 20 hours. Due to the finite lifetime the storage ring is emptied of electrons twice per day (8:00 and 18:00) and refilled. The refilling process involves a two stage accumulation process. The first stage uses a microtron as a pre-accelerator and a 53-505 MeV 1Hz ramped booster. The second stage is the accumulation of a nominal 200 mA of stored current, which is then ramped from 505 MeV to 2.5 GeV. The machine is then left unattended until the next injection time, which leads to two important demands on the control system, namely, robust and sensitive alarm notification in the case of reduced machine performance and a very intuitive GUI machine interface supporting pictorial machine representation; intuitive as a single operator will only attend to the machine for approximately 10 hours per 2 months due to shifts. The original ANKA control system, Advanced Control System (ACS), which was installed in 2003 [1], did not have these functionalities when first commissioned. This, coupled with the fact that the ACS ANKA specific hardware was becoming increasingly difficult to maintain, leading to more control system failures, a decision was made to make a complete upgrade of both control system and hardware. The migration to an upgraded control system, which in this case also means new interface hardware, is made ever more challenging due to the ANKA requirement of machine operation of around 220 working days of the ~250 working days a year available. Therefore, migration has to be done piece wise, taking care at every stage that the installation of new hardware and GUI panels are totally non-intrusive to the operators and machine operation.

CONCEPT

The overriding motivation is to increase mean-time-between failures due to the control system by introducing: alarming, post-mortem capabilities, comprehensive diagnostic tools and visualisation of performance data displayed in an automated way. To achieve this in this case means: replacement of ACS hardware interfaces and storage ring field bus, removal of ACS device servers running on Windows XP machines, replacement of Java based GUI panels, and where required replacement of complete hardware units e.g. power supplies.

DESIGN APPROACH

In addition to the challenges mentioned in the introduction, as an existing facility the hardware of the ANKA machine was already defined and is in daily operation, where many dependencies have to be considered. Keeping the concept described above in mind, a bottom-up approach was taken.

First the existing control system hardware layer was logically broken down into four parts:

1) Supervisory control and data acquisition (SCADA). This can be considered to have a slow data rate of ~1-10 Hz data readout. This is used for general hardware configuration and monitoring data for the operator.
2) Fast Data Acquisition (FDAQ) and control. An example would be the 10 kHz ramping of the power supplies mentioned in the introduction. In the ACS system this is achieved with local ADC boards called ZEUS [1].
3) The field bus, originally LonWorks.
4) Archiving, originally MSSQL.

Secondly, parts of the machine were grouped together that could be considered a "fully contained upgrade". This means that these components had no or minimal control-system dependencies to or from components outside this cluster and could be completely installed within one shutdown, which usually is in the order of two weeks. An example would be the timing distribution that originally consisted of a group of several signal generator devices which was moved to an EVent Generator (EVG) from Micro-Research Finland [2].

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Before starting out on a new venture one should consider what has been learnt from the last; in this case from the ACS system. The ACS control system was a very cost effective solution and has stead ANKA well over the last decade. The clear lesson for ANKA was that the new venture must consist of common, well supported, Commercial-Of-The-Shelf components (COTS), for long term maintainability. Another lesson learnt was, as with ACS, a common solution should be found i.e. do not mix different buses, interfaces or control systems. With this the first upgrade decision could be made. The following sub-sections describe the decision process flow.

Field Bus

Which field bus to use needed to be decided on first as this dictates most other aspects of interfacing. For ANKA the field bus would only be used for the SCADA system (this does include the slow interface to the FDAQ). Therefore, a simple count of the number of physical devices to be controlled and how many channels to be read out from each, in this paper we take the EPICS term of PV to mean a readout channel, and multiply the number of devices by the number of PVs gives the data demands. For the bandwidth this number is then multiplied by the readout rate. Table 1 gives a non-comprehensive indication of the type of devices to be read out and the number of PVs per device. As can be seen the number of PVs per device varies considerably e.g. a beam position monitor (BPM) uses 500 PVs compared to a power supply that requires only 30.

Table 1: Process Variables

Device Type	# Devices	# PVs per device
BPMs	44	500
Power Supplies	200	30
RF system	10	100
Cameras	8	20
VAC pumps	40	100
Timing Distribution	10	700

The readout rate can vary per PV. Some PVs are only changed manually, for example to set a value; others must be read out at 1-10 Hz. Summing up gave ~25000 PVs to be readout, but only 1000 of them at 10Hz and 2000 at 1Hz. Gigabit Ethernet can easily provide the bandwidth required here. Furthermore, Ethernet has become a much standardised product with the physical layer being robust, scalable and common place. We have chosen to use copper Ethernet cables over the use of fibre optic as copper, with its differential signalling and long distance capabilities (ANKA storage ring is 110.4 m circumference) has good signal integrity and is less complicated than the installation of fibre. Most modern hardware is equipped with Ethernet TCP/IP capabilities as standard and for a SCADA system TCP/IP makes perfect sense. If the future demands start to load the field bus then moving up to 10Gbit Ethernet is already feasible.

Hardware Devices

At the inauguration of ANKA around 70 % of the controlled electrical/electronic hardware devices were semi-custom built for ANKA purposes. This dedicated hardware suffers from limited spares and upgrade possibilities. It is also clearly showing signs of ageing and, as stated earlier, is locked in with the old bus interface. A directive has been set that where possible old hardware will be replaced with new COTS devices, and that the number of different devices should be kept to a minimum; thus providing a common ANKA solution where the skill base requirements are reduced to just a few different types of hardware. The other clear advantage of new COTS technology is that it offers far greater performance in speed and reliability. Newer devices are much more robust against ElectroMagnet Coupling (EMC), they generate less EMC and ground noise coupling and in general offer comprehensive status and self-diagnostic information.

SCADA Control Software

Keeping in line with the COTS approach commercial control systems were considered. One in particular, named SIMATIC WinCC OA from Siemens was considered to be suitable. Under its original name of PVSS this control system was heavily used at CERN for its detector SCADA systems (not the LHC machine), and the ANKA beamlines had adopted this for their use several years ago. However, for use as a machine control system it was simply not practical to develop all the drivers needed to interface to a synchrotron's rather complicated hardware. This product was also under license and was cost prohibitive. The next best thing to COTS is a widely used synchrotron community control system. There were two very widely used possibilities, namely EPICS [3] and TANGO [4]; both open source. Both of these systems were compared in detail for ANKA use and in general where one system would win on one point, the other would win on another. The final decision to use EPICS was mostly motivated by the proven reliability, the ease in which serial devices can be added to the control system and the availability of an extensive library of commonly used synchrotron hardware control panels and Input Output Controllers (IOCs). In particular, the Libera BPM EPICS driver from Diamond [5]. The Diamond BPM driver provided a simple, reliable and yet comprehensive solution for configuring the devices, retrieving data for slow-orbit feedback, and accessing the diagnostics features. In particular, the ready-to-use EDM panels, which come with the driver, proved to be very useful in the commissioning phase. The Libera BPM devices are discussed further in section IMPLEMENTATION.

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Fast control and Diagnostics

For FDAQ, such as: the processing for the fast feedback orbit correction matrixes, the booster ramping, low level RF, and RF diagnostics and interlocks, to name a few, the MicroTCA.4 [6] system has been chosen. This technology is rapidly evolving to become a viable standard for large-scale research facilities of the high-energy physics and photon science community. The MicroTCA standard is targeted at supplying COTS chassis, power supplies, mezzanine cards and carrier hubs. Furthermore, DESY, which is a large scale photon science facility in Hamburg, Germany, has built a consortium of users, industrial partners, and developers which has already allowed access to such hardware as Analog/Digital converters, Low-Level RF, and much more. Although these very high performance units are probably over powered for most of ANKA use, they offer a common solution to all of ANKA's FDAQ needs, are cost effective compared to VME, are well supported, have EPICS control and are expected to become widely used in most facilities.

Cassandra Database

In order to help operators solve machine errors, or to improve running conditions an ANKA archive system is essential that can hold years of data at an incoming data rate of up to 10Hz for several thousands of PVs. The archiver must be very robust in operation as this data is also essential for yearly running and radiation reports. The Cassandra Archiver [7] has been installed at ANKA to provide a simple to use, scalable data-archiving solution. It seamlessly plugs into the Control System Studio (CSS), discussed later in this paper, providing quick and simple access to all archived PVs.

Matlab Middle Layer

The MATLAB Middle Layer (MML) [8] is a collection of scripts for the MATLAB programming environment, designed to control and measure parameters of an accelerator. This software creates an abstraction layer enabling the user to write scripts independent of the accelerator's control system. For most uses, even the magnet lattice of the accelerator itself is abstracted. Thus, scripts written for one accelerator can be used for a different accelerator, even if this accelerator has a mostly different design. For a detailed description of ANKA MML refer to [9].

IMPLEMENTATION

To pave the way for a 100 fold increase in devices that communicate over TCP/IP being used inside the storage ring a completely isolated private network has been commissioned. The first devices to be used over this network were 40 new BPM electronic systems. These BPMs not only increased the reliability of the control system substantially but also offered much more in beam diagnostics such as first turn read out, turn by turn readout and a 10kHz fast feedback read out of the beam position. For a detailed description of the ANKA BPM system refer to [10].

One challenge of the new BPM electronics was to move the control system high-level client for orbit correction to accept an EPIC connection instead of the old ACS while still allowing at the same time to control the corrector magnets that remained in the old control system. This was achieved by developing a software gateway that would allow EPICS clients to transparently access process variables in the ACS control system. The intention is to replace these correctors with Ethernet based, fast response magnets and power supplies so as to take advantage of the BPM fast feedback correction system now available.

Another new device installed in the ANKA storage ring is the NANO wiggler. Full control was developed with EPICS and the graphical user interface CSS as a test case for new tools. This has set an ANKA standard which can be applied to any newly integrated device so as to keep the whole control and operation of the machine completely homogeneous.

All new ANKA GUI panels are developed in CSS. EPICS alarming capabilities in connection with the BEAST alarm server tool-kit from the CSS bundle are used as an alarming solution. To accommodate ANKA future requirements, as well as ANKA legacy solutions, we have decided to extend the basic functionality of BEAST with additional features in order to manage the alarming for different machine operation states.

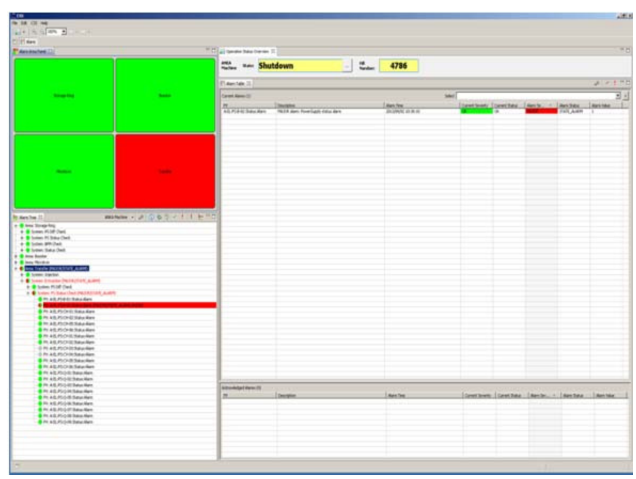

Figure 1: ANKA alarm panels. Top left corner represents the grouping on the machine into Storage Ring, Booster, Transfer Lines and Microtron. A single alarm due to an extraction power supply having different read and set values is shown.

Since the database of alarm sources is been populated from scratch, we have been able to automate the management and creation of alarm sources to build-up their alarm trees. An example of the alarm panel is shown in Fig. 1. In the top left corner the machine is

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represented in its four parts: Storage Ring, Booster, Transfer Lines and Microtron. The Transfer Line has an alarm; clicking through the tree on the left lower column is one way that an operator can access the details. In any case the alarm is displayed in the main central area until it is acknowledged and removed. In this case there is an alarm that a single extraction line power supply has a different read back value to its set value. Alarm history can be displayed in the lower section of the window. Filters that respond to the status of the machine, for example, here we have 'Shutdown' will disable many of the alarms, such as RF alarms as the cavities are off and should not react to a low temperature in this status.

Another example of a new GUI is shown in Fig. 2. Here the top panel of the CSS is split into two halves. On the left side of the window all elements of the EPICS controlled devices are accessible. On the right side a pictorial representation displays the elements to be controlled; in this case the florescent screens. The right hand screen is divided into more sub-windows on selection of further buttons, or alternatively, any sub-window can be dragged onto the desktop; for this reason we use a four monitor computer.

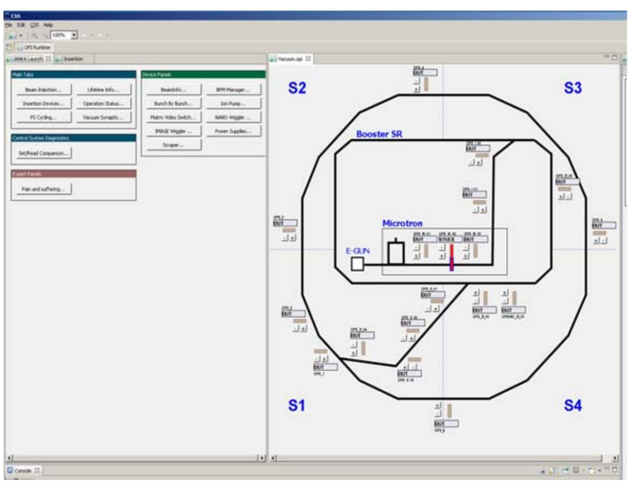

Figure 2: ANKA CSS panels. On the left side gives access to any device under EPICS control, and on the right side the pictorial representation of the selected devices.

CSS has trend plotting capabilities that can have any number of PVs dragged and dropped into the trend window. A simple time span button allows data to be updated at the incoming data rate, plus any historical Cassandra archived data to be retrieved and concatenated. Together with the Cassandra database this makes for a very easy to use, very flexible and fast trend tool. Automated post mortem capabilities will be added.

Power supply studies (in this case in the range of 10-200 V and 1 – 200 A) showed that in general companies are well behind on the TCP/IP protocol and in most cases either have no capabilities, or have used some general purpose Ethernet to RS232 adapter and have simply fixed it inside the power supply casing. From the units with Ethernet ports from different venders that were studied only two did not suffer from protocol issues. Some examples are that only one port on the device could be opened at one time, and the release of the port was not robust. Another was just the loss of connection on a regular basis. These substandard devices most often did not support SSH or telnet and were difficult to communicate to. It should be mentioned however, that all devices tested used the Standard Commands for Programmable Instruments (SCPI). In conclusion it was much harder to find a high performance power supply unit that hosted Ethernet than first thought. After robust testing of both the analogue and interfacing capabilities we chose Delta [11] switched mode power supplies. Sections of the injection line and extraction line, which utilise dipole and quadrupole magnets have been exchanged and successfully run for the last month; the remainder will be exchanged at the next shutdown.

SUMMARY

ANKA has a clear road map for the complete upgrade of machine devices and migration to the EPICS/CSS control system. The foundations have been laid, and already a substantial amount has been upgraded.

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