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IMPROVEMENTS OF THE ELBE CONTROL SYSTEM INFRASTRUCTURE AND SCADA ENVIRONMENT

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Abstract

The ELBE Center for High-Power Radiation Sources is driven by a 35 MeV C.W. electron linear accelerator, driving diverse secondary beams, both electromagnetic radiation and particles. Its control system is based on PLCs, fast data acquisition systems and the industrial SCADA system WinCC. In the past five years, requirements for availability and reliability increased, while at the same time many changes of the machine configuration and instrumentation needed to be handled. Improvements of the control system infrastructure concerning power supply, IT and systems monitoring have been realized and are still under way. Along with the latest WinCC upgrade, we implemented a more redundant SCADA infrastructure and continuously improved our standards for software development.

ELBE CONTROL SYSTEM OVERVIEW

The ELBE [1] control system has been using commercial and Windows based control system components right from start [2]. This decision was made due to the available expertise, manpower and time budget. Design started in the late 1990s, so it became a textbook example for IEC62242 automation system structure during its first decade that still dominates. The ELBE CS uses interconnected Siemens S7-300/400 PLCs [3] with distributed I/O-stations for basic level equipment control and machine protection, grouped by their technological tasks like vacuum, auxiliary media, PSS, MPS or beam control, see figure 1). WinCC V7.3 by Siemens [4] serves as SCADA system in a server-client architecture. Fast data acquisition (DAQ) systems use National Instruments (NI) hardware and LabView applications [5], usually combining a real time DAQ system with a Windows GUI via shared network variables and, if necessary, with the PLC system using OPC DA [6]. A variety of in-house built hardware for i.e. beam diagnostics, MPS, low level RF has been integrated by hardwired I/O, field bus interfaces or LabView applications. Critical MPS functions are covered by hardware based systems which are PLC-configured according to the actual beam mode and path [7].

PLC AND WINCC SOFTWARE IMPROVEMENTS

Although available, object oriented PLC programming options were rarely used during the first commissioning steps of ELBE. With its latest larger facility upgrade from 2012 on, we made the paradigm shift in this field. Standard components, hardware or virtual, are represented using structural PLC data types, see figure 2. The PLC code is a set of functions using these data instances as input/output parameters. The PLC data types are used almost one-by-one in WinCC, too.

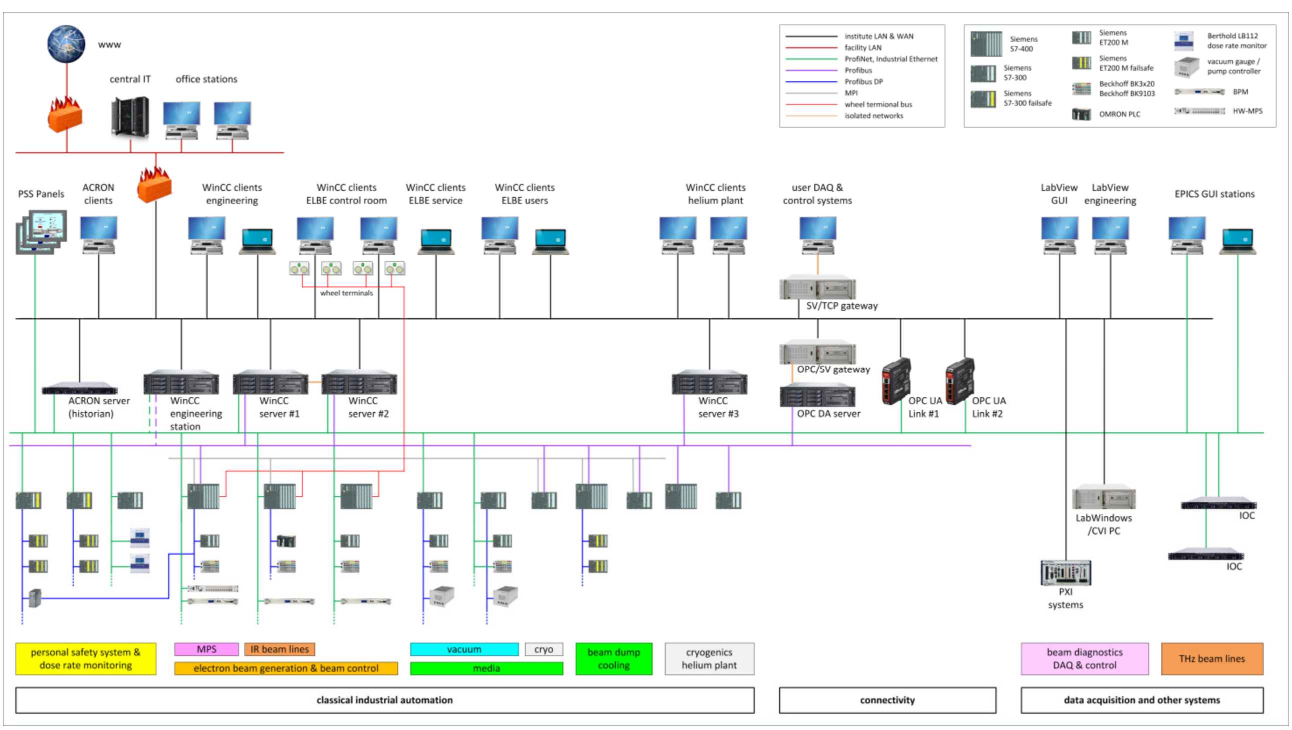

Figure 1: Overview of the ELBE control system.

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The structural WinCC variables then get a prefix, usually the component name, which enables efficient GUI design by templates [8]. The templates are used with individual prefixes for the single components. By parameterization, also different ways of hardware integration, different functionality or different device types can thus be represented by one single GUI template in the same way, while on PLC level the device driver software is different.

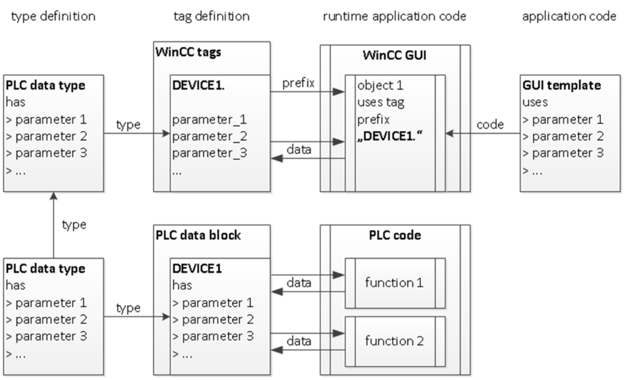

Figure 2: PLC and WinCC object oriented data handling.

IMPROVED FIELD BUS ARCHITECTURE AND SUPERVISION

Due to its history of constant upgrades and change, the ELBE CS is quite heterogeneous in its hardware. Starting with Profibus only, we now integrate devices by Profinet-IO communication or TCP/IP Send/Receive connections wherever possible. The main PLCs have been equipped with Profinet interfaces to replace Profibus based communication and to add Profinet IO master functionality. Few smaller PLCs have not been upgraded this way, for this would have meant replacing lots of hardware just for compatibility reasons, and many slave devices are still only available with Profibus interfaces. The two former Profibus multiple-master systems for WinCC were reduced to just one system.

A series of non-reproducible failures lead to improvements of the overall Profibus system. First, bus settings were changed to the necessary baud rates to improve the electrical signal levels. Having thus brought PLC cycles and Profibus-DP cycles very close, we experienced even more connection failures. One reason was improper installation (segmentation, termination) within the electrical system, which could easily be fixed. The other reason was incompatibilities between different optical components, even of the same vendor. These could be corrected by replacing media converters and slave couplers, or by inserting optical attenuators, self-made from optical filters. The new media converter series (Siemens OLM V4 series) now allows monitoring the optical transmission levels at the main nodes. Further, for long time supervision and failure analysis, we installed a centralized commercial monitoring system for all Profibus DP lines (TH Scope and TH Link [9]) and improved our skills and tools for real time bus analysis. Failures could be reduced to a few incidents per year for Profibus DP as well as for WinCC /PLC connections. As a next step, PLC based system monitoring based on acyclic communication is foreseen to reduce the impact of remaining failures on the beam operation according to the current beam option.

To monitor the Profinet / Industrial Ethernet infrastructure, we run a SINEMA Server Application [10], but which is still in the testing phase.

WINCC UPGRADE

In 2015 we upgraded WinCC from V7.0 to V7.3, along with some major changes in the system architecture. Before that, ELBE had one SCADA server, covering the complete functionality for process data management, data logging, alarming and user databases, and a second server for cold redundancy. Project changes were done from client stations directly within the server project at runtime. Under certain circumstances, this can lead to inconsistent data bases, followed by a server failure up to one hour. A server hardware failure would have led to about four hours of machine downtime for switching to the second serve with loss of some data logging.

Before setting up the new servers, a compatibility revision was carried out carefully for all relevant components, i.e. operating system, field bus interfaces, virus scan software, remote access software and so on according to vendor specifications. Due to its 15 years engineering history over several major releases, we did a large cleanup of the WinCC project based on cross reference analysis and script diagnostic tools. The most significant changes were then made by migrating from cold to hot server redundancy and by integrating the WinCC project into a Step7 project hosted by an engineering station (ES) [8], see figure 3. Project changes are now done offline and then uploaded to the servers. Simple changes are uploaded at runtime automatically, while major changes need a manual sequential upload to both servers after stopping runtime, but without losing operability of the machine or data logging. The ES has optional connectivity to the process, so critical changes can be tested in runtime here before updating the servers. Data consistency and connectivity management between the servers at runtime is automatically covered by WinCC. This reduced our SCADA system failures to zero. Current efforts focus on setting up a redundant process historian to minimize the amount of historical data to be handled by the servers and to improve multiple platform access to all historical data.

The main problem we had with the architecture (and did still not solve completely) was automatically keeping the consistency of user archives between the source project and the server runtime databases, since at ELBE, the user archive data base structures can be changing at runtime.

The backup strategy for this project is weekly backups of the Step7 integrated source project and the master server runtime project, as well as instant continuous backups of the tag logging and alarm logging data to local network storage and in addition to the institute`s central data storage.

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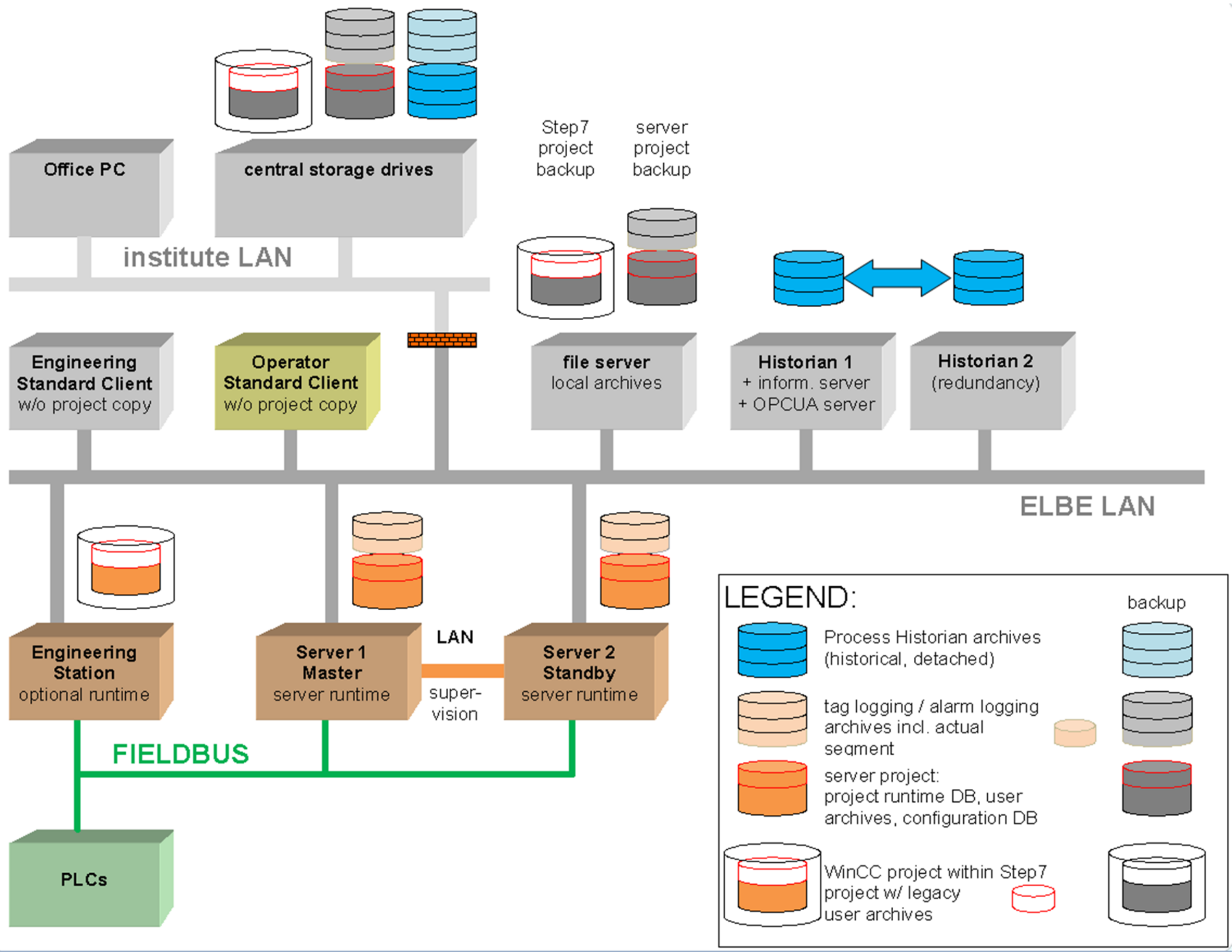

Figure 3: The new WinCC system architecture.

EVALUATING OPC UA AS A NEW CONNECTIVITY STANDARD

Different ongoing projects and recent hardware changes necessitate a general improvement of the ELBE CS connectivity for other (non-Siemens) systems. Since OPC DA is aged out and not suitable for Linux systems, we have evaluated different approaches for OPC UA connectivity.

- test of third party OPC UA gateway (IBH [11]) as a possible successor of OPC DA
- test of Siemens communication interfaces (CP 443-1 OPC UA version)
- use of native and third party [12] OPC UA client channel for WinCC
- Trilateral project with DESY and TU Dresden for OPC UA stack implementation of MTCA4 hardware of the new digital low level RF system.

A contribution by R. Steinbrück to this conference gives more detailed information on this activity. All of the technologies we implemented and tested showed that there are still a large number of open issues in the OPC UA field to be solved by industry before we can speak of a well-established technology [13].

ELECTRICAL INFRASTRUCTURE

Any control system is as available as its electrical infrastructure. Triggered by a UPS fault and pushed by some hardware legacies, we have centralized and straightened our UPS and NEA infrastructure. Figure 4 shows the power supply infrastructure for CS related components. The load distribution of CS hardware among three individual UPS devices was bundled to one UPS cluster system with 2+1 redundancy. A completely new diesel generator was installed to buffer safety and security related infrastructure (as before), and now also CS hardware on the controller side. This enables detailed investigation of after a power outage. Further, we completely buffer all safety-related CS hardware (MPS, PSS), as well as critical vacuum and cryostat components and beam dump hardware. With the current installation the UPS system has a backup time of roughly one hour, the diesel generator is designed for a 48h backup time. All critical servers, LAN and fieldbus infrastructure or PLCs are connected both to UPS and standard mains supply if redundant power inputs are available.

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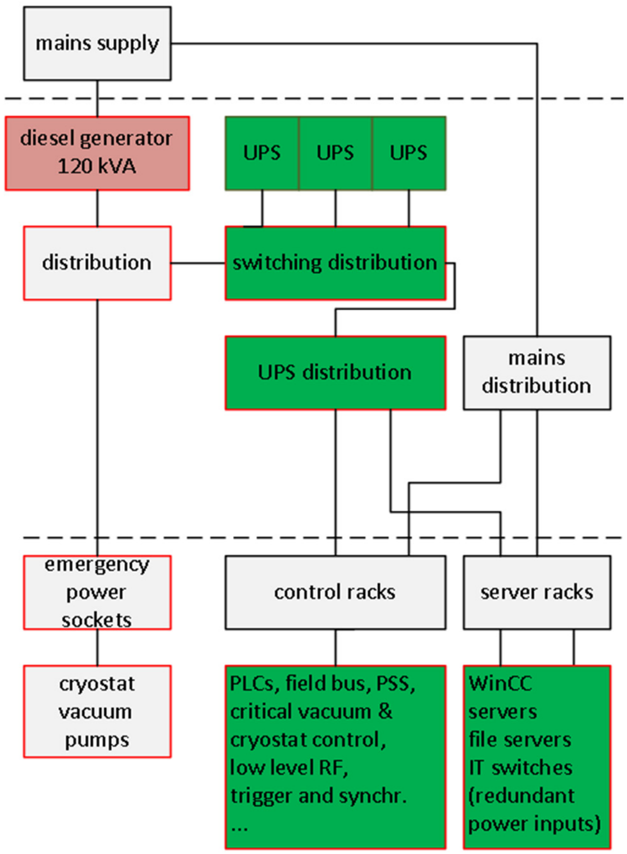

Figure 4: Electrical infrastructure for control system related components.

CONCLUSION

Uptime and availability of the ELBE Control system could be significantly improved, especially the new WinCC architecture. Object oriented data handling lead to reduced engineering efforts at less risk of causing malfunctions. Future efforts will address improved field bus and devices monitoring as well as long term data storage.

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