ISBN: 978-3-95450-238-7 ISSN: 2226-0358 doi:10.18429/JACoW-ICALEPCS2023-TUPDP022

DALI CONTROL SYSTEM CONSIDERATIONS

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Abstract

The Dresden Advanced Light Infrastructure is a future infrastructure under consideration at the Helmholtz-Zentrum Dresden-Rossendorf. In the current conceptional design phase, we are surveying different control system options. To benefit as much as possible from community experiences with different control systems, in 2023 a survey was conducted and participants from accelerator and light source facilities world-wide were invited. The results of that survey are presented and conclusions for our center are drawn.

INTRODUCTION

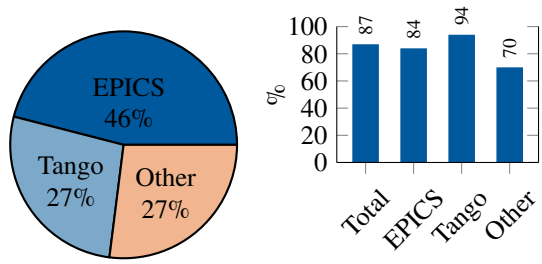
The Dresden Advanced Light Infrastructure (DALI) [1] is part of the German national *Helmholtz Photon Science Roadmap* [2]. It will be a high-field source of intense terahertz radiation based on accelerated electrons and the successor of the Center for High-Power Radiation Sources (ELBE) operated at HZDR since 2002. In the current phase of DALI the conceptional design report is in preparation and there are ongoing considerations which control system to use best.

As a background note, due to historical reasons the ELBE control system is based on industrial automation products. Namely Siemens Simatic S7 PLCs [3, 4] on the field level and WinCC [5] as SCADA system for HMI and data archiving. Even when this system served the purposes of ELBE operation quite well during the last decades it lacks openness and interfaces for modern scientific tools like machine learning and artificial intelligence. Hence there is a strong request on the part of machine physicists and scientific users to search for control system alternatives for the new DALI facility.

To get on overview of the different control systems (CS), that are in operation at other accelerator based facilities we conducted a survey. With that we intended to benefit as much as possible from the community experience with different types of control systems.

CONTROL SYSTEM SURVEY

In 2023 we conducted an online survey among invited participants. We invited 38 participants from 22 different particle accelerator facilities and light source facilities, respectively. We picked participants from facilities of similar size, similar machine types and field of research. Contacted participants are based in the USA, Brazil, Asia, and Europe. In total, we received 21 responses from 15 different facilities. Except for one American and one Asian facility all participating facilities are located in Europe. The results presented in the following are not representative for the whole community, but show a clear picture of the usage of different control systems in the community. It turned out that 46 % of the participants are using EPICS [6], 27 % are using Tango [7] and 27 % are using other control systems (e.g. DOOCS [8], TINE [9] or LabView [10]), as shown in Fig. 1a. Therefore, we decided to group the results into three control system categories – EPICS, Tango and Other. This allows to identify differences between those three categories.



(a) Fractions of CS used by the participants.

(b) Overall satisfaction.

Figure 1: CS categories and CS satisfaction.

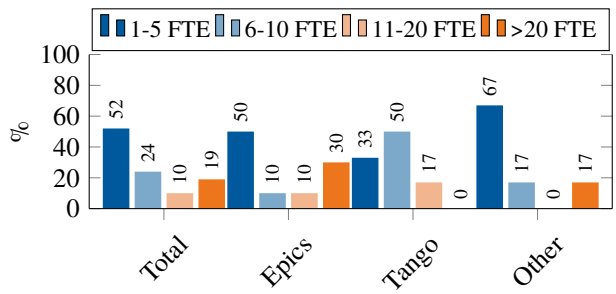


Figure 2: Number of FTEs needed to maintain the CS.

In terms of control system operation time, we noticed that half of the control systems of participating facilities are in operation for more than 20 year and the other half is in operation less than 10 years. This observation is independent of the control system category.

The overall satisfaction with the control system in use, as shown in Fig. 1b, is quite high for EPICS (84 %) and Tango (94 %) and slightly lower for Other (70 %). The following control system features were mentioned as missing:

- High data rate support
- Synchronized data processing at a rate above 100 Hz
- Encryption of the network communication
- Support for multidimensional data type (> 2D)

Development Efforts

As shown in Fig. 2 50 % of the EPICS participants and 67 % of the Other participants state taht their CS is maintained by one to five full time equivalents (FTEs). 50 % of

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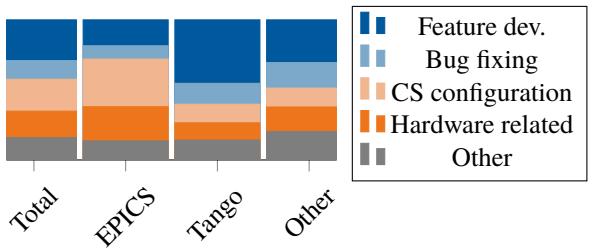


Figure 3: Development effort per task.

the Tango participants are maintained by six to ten FTEs and only 33 % use one to five FTEs. In case of EPICS also a significant amount of 30 % is maintained by more than 20 FTEs.

For all categories about 40 % of the work is related to the frontend software and 60 % is related to backend software. In the survey we understand e.g. GUI software as frontend software and backend software is used to integrate devices to the CS (i.e. device drivers). Figure 3 shows the fractions of time devoted to different development tasks.

Notably, the CS configuration work is dominant in case of EPICS, whereas feature development dominates the development effort in case of Tango.

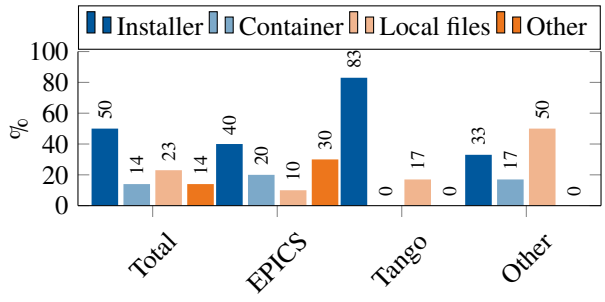
The overall satisfaction with the community support is quite high for EPICS (72 %) and Tango (85 %). 52 % of EPICS and 59 % of Tango participants make use of the community support. In case of Other CS the support usage is only 14 % and the satisfaction is only 42 %. In addition to the community or vendor support of the CS, many participants make use of external partners, which are supporting EPICS as well as Tango. For those two CS multiple partners are available on the market and have been named by the participants.

CS Software Distribution

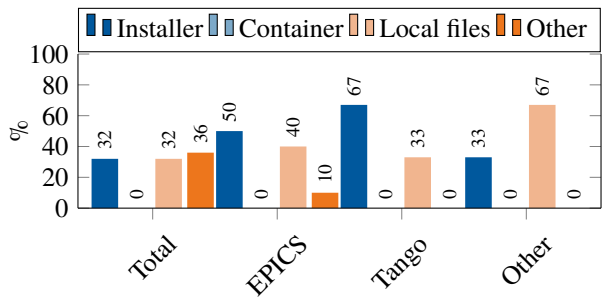
All EPICS (except for one system used for cameras) and Tango participants run their backend CS software primarily on Linux systems. In contrast, 50 % of the Other CS run their backend software primarily on Windows. In terms of software distribution, Fig. 4 shows different approaches used by the participants. Clearly, Tango seems to prefer installers (e.g. debian packages). 50 % of the Other CS distribute their backend software via local files that are copied to the target machine. In case of frontend software, this option is also used by more participants using EPICS and Tango. In general, software distribution based on containers seems not to be very popular, neither in case of the backend nor in case of the frontend software. 18 % use front end software that does not depend on the operating system, i.e. Java.

CS Interfaces

In general, the CS might provide machine-to-machine (M2M) interfaces, mainly used in the backend services, as well as human-to-machine (H2M) interfaces used e.g. for scripting. Concerning M2M interfaces we observed that 68 % of the participants need to interface their CS to another



(a) Backend.



(b) Frontend.

Figure 4: Software distribution.

CS type, e.g. Tango interfaces to EPICS. 32 % need to interface the industry standard OPC UA. This correlates to the fact that 32 % use OPC UA to integrate industrial PLCs to their CS. All participants stated that they have to interface PLC subsystems. Other protocols used to integrate PLCs are Modbus (31 %) and Beckhoff ADS (14 %). Most participants use Siemens PLCs (77 %) followed by Beckhoff (41 %), which is biased by the participants that are mainly based in Europe.

Concerning H2M interfaces, almost all participants stated that their CS provides a scripting interface. In case of EPICS and Tango a Python based interface is supported by the CS of all corresponding participants. In addition, C++ (EPICS: 67 %, Tango: 17 %, Other: 40 %) and Java (EPICS: 56 %, Tango: 17 %, Other: 40 %) are mainly supported. Which protocols are supported depends on the CS. In case of EPICS usually Channel Access/PV Access is used, whereas in case of Tango ZeroMQ is predominant. However, the access to the CS is in most cases read-only as shown in Fig. 5a. If write access is granted users have to be in the CS network. Else read access is granted typically via a gateway to the CS network.

CS Security

Almost all CS are operated in a dedicated network, that can be reached only via gateway machines. In the CS network none of the participants is using encryption. Host verification is used by 18 % of the participants. 18 % of the participants say that they use host verification partially. 13 % of the participants do not know if encryption or host verification is used in their CS. Remote access for operators is

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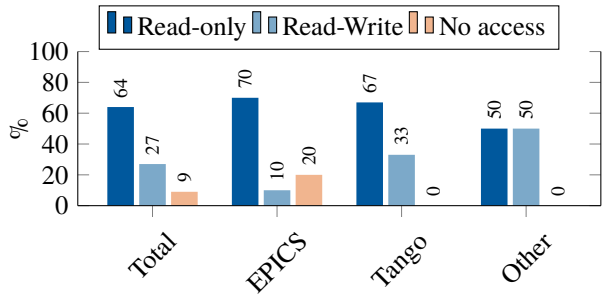
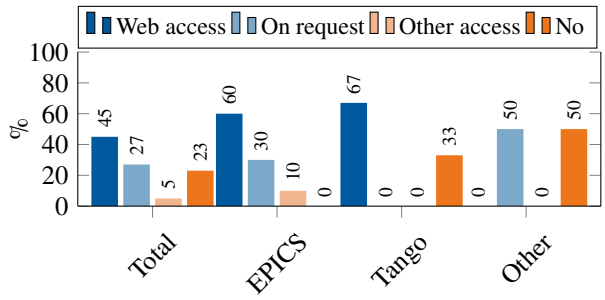


(a) Access to live data.



(b) Access to archived data.

Figure 5: CS data access and control for users.

not possible in 50 % in case of Tango, whereas it is possible in 60 % in case of EPICS via a gateway. VPN connections (EPICS: 10 %, Tango: 33 %, Other: 17 %) and Web based access (EPICS: 20 %, Tango: 0 %, Other: 17 %) are not popular to grant access to the CS for the operators.

CS Archiving and Documentation

All participants that use EPICS use the EPICS Achiver Appliance, which is based on Google Protocol buffers for arching in combination with a database for storing the archiving configuration. The dominant database type is MySQL as it is used by 60 % of the EPICS users. In case of Tango the situation is more diverse. 50 % are using TimescaleDB and 33 % use MariaDB for data archiving. Other CS mainly (67 %) use local files for archiving. Here the dominant file format is HDF5. Apart from the archiving solutions mentioned above ASCII files were mentioned as well as a NoSQL database (i.e. Cassandra) and a commercial solution (i.e. Elasticsearch). If and how users of the facility can access archived data, e.g. archived experiment data or machine data for offline data analysis, is shown in Fig. 5b. In most cases, users of facilities that use EPICS or Tango can use a web interface to access historical CS data. On the other 50 % of Other CS state that there is no access is possible and 50 % of Other CS only provide archived data on request.

CS settings are stored in different databases (e.g. 50 % use MySQL in case of Tango and 30 % use PostgreSQL in case of EPICS), but mainly local files and network shared files are used at least by EPICS and Others as shown in Fig. 6. Often multiple solutions are used, which explains e.g. the high percentage of local files (60 %) and network file (50 %)

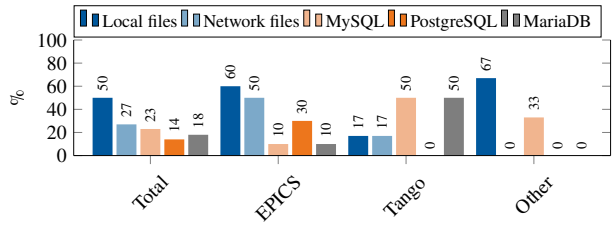


Figure 6: CS settings management.

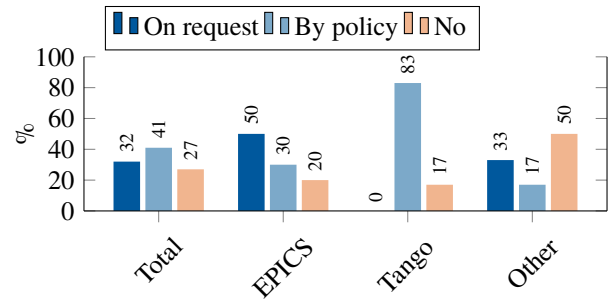


Figure 7: Archiving of user data. On request means that users explicitly request the archiving, whereas at some facilities archiving of user data is required by the data policy.

in case of EPICS.

We also asked if participants store data acquired by users of the facility. 18 % store all data generated by user experiments, whereas 77 % only store selected user data. Figure 7 shows that storing the user data results from the data policy of the facility for 83 % of the Tango participants. For EPICS and Others data is mainly stored only on user request.

Miscellaneous CS Features

As shown in Fig. 8, most participants have integrated a logbook into the CS. It is mainly accessed via a web access. 40 % of EPICS participants can access the logbook directly from a CS GUI. 10 % of EPICS, 33 % of Tango and 17 % of Other participants state that they do not have a logbook integrated to their CS. 70 % of EPICS participants state that they can link CS panels to logbook entries, which only 17 % of Tango and 33 % of Other participants state. In addition, 60 % of the EPICS participants can link alarms to the logbook. This is possible for 17 % of Tango and 67 % of Other participants.

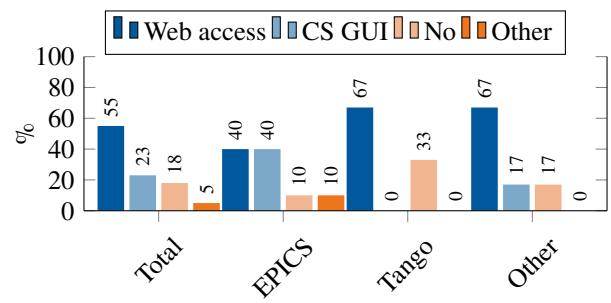


Figure 8: Logbook integration.

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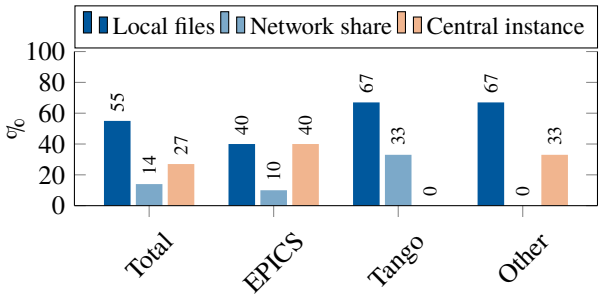

Figure 9: Logfile handling.

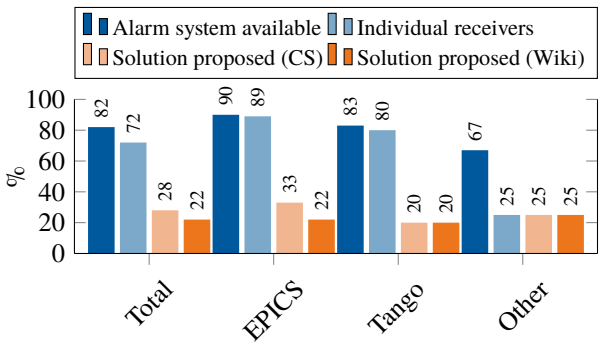

Figure 10: Details about the alarm system.

The handling of logfiles, that include logging messages from frontend or backend applications, is shown in Fig. 9. Mainly logfiles are stored locally by Tango (67 %) and Other (67 %) participants. In case of EPICS 40 % store logfiles locally, but 40 % use a central instance for managing logfiles.

Alarm systems are used by the majority of the participants as shown in Fig. 10. In most cases the alarm system allows to define alarm specific receivers and groups of receivers (see Fig. 10 data called *Individual receivers*) instead of a general alarm raised in the CS. Similarly, for all CS categories, in about 25 % a solution to resolve the alarm is directly proposed in the CS and equally in about 25 % a solution is proposed in a Wiki page linked to the alarm. If an alarm system is available, the alarm is raised and visible in the CS in all cases. In addition, e-mails (EPICS: 33 %, Tango: 80 %, Other: 0 %) and SMS (EPICS: 67 %, Tango: 60 %, Other: 25 %) are used to inform about alarms.

In general, sequencers are available in the CS of all participants. We asked how those sequencers can be configured. The result is shown in Fig. 11. Mainly, they can be configured directly by CS GUIs. Some participants stated that they can only be configured by dedicated software and some participants stated that the sequences are hard coded in the backend devices and can not be configured by software. 13 % of all participants, stated that they use a mixture of sequences that are hard coded on backend devices and sequences that can be configured by software.

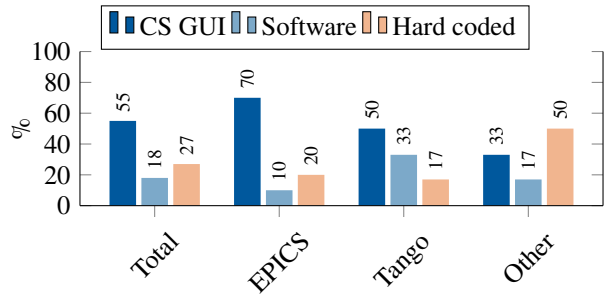

Figure 11: Configuration options for sequencers.

CONCLUSION

In order to evaluate different CS to be used with the Dresden Advanced Light Infrastructure (DALI) a world-wide survey among light source and accelerator facilities, similar to DALI, was conducted in 2023. We received 21 individual responses from 15 different facilities. Most participants used EPICS (46 %) and Tango (27 %). In both cases, rather new CS implementations, that are under construction or in operation for less than 10 years, as well as old implementations, that are in operation for more than 20 years, are in use. The overall satisfaction for those two CS is high and also the satisfaction with community support is high. External partners are available in both cases, which is important for us since it allows to outsource the development of certain CS subsystems. Both CS offer a complete set of features (e.g. archiving, alarm system, interfaces) and therefore both seem to be reasonable CS candidates for DALI. In the end, centre specific boundary conditions will support the decision for one or the other CS. E.g. at the Helmholtz-Zentrum Dresden-Rossendorf (HZDR) already other projects make use of EPICS. In addition, experience with EPICS was already gained at ELBE. ELBE includes subsystems that make use of EPICS already today, i.e. the recently implemented timing system [11] or can be easily switched to EPICS, i.e. the LLRF system [12] thanks to the ChimeraTK framework [13].

ACKNOWLEDGEMENTS

The authors like to thank all the survey participants for their support and participation.

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