Open XAL DEVELOPMENT FOR XI'AN PROTON APPLICATION FACILITY

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Abstract

Beam commission tools for Xi'an Proton Application Facility (XiPAF) will be developed based on Open XAL. In this paper, we present preparations made for adopting Open XAL in XiPAF, including a newly designed database schema based on MySQL, modifying db2xal application based on database schema to create optics file automatically. We also add time-dependent nodes in XiPAF's online model to meet the need of energy ramping in synchrotron. A set of high-level applications as well as a new virtual accelerator is under development.

INTRODUCTION

The Xi'an Proton Application Facility, composed of a 7 MeV H- linac injector, a 230 MeV synchrotron and two experimental stations, is under construction and will provide proton beam for the research of single event effect (SEE) [1]. Open XAL is an open source framework used for developing high-level accelerator scripts and applications. The online model and applications built in Open XAL have been tested by SNS, CSNS and other similar facilities [2]. Open XAL provides a complete solution for developing high-level applications in EPICS control system of proton facilities. This is the main reason why we choose Open XAL to develop our high-level applications. In spite of this, modifications and development are still necessary to adopt Open XAL in XiPAF, because layout, parameters, diagnostics and operation scenarios may be different from each machine, and commission is actually a machine-specific work.

Figure 1 shows schematic layout of EPICS control system and high-level controls based on Open XAL. Virtual accelerator (VA) is configured as a portable channel access server (PACS) as well as a channel access client (CAC), so that it can be used to debug OPIs and high-level applications. Virtual magnet (VM) is a soft IOC serving as a unit conversion server of electro-magnets. Accelerator database stores design values, misalignments, snapshots and other important data of XiPAF. Each component is connected with each other through local network.

In order to debug control system and high-level applications without a real machine, tools such as accelerator database, virtual accelerator and virtual magnets should be built in prior. Open XAL development for XiPAF consists of three parts, namely accelerator database, virtual accelerator and high-level applications, which will be developed step by step and discussed in detail in this paper.

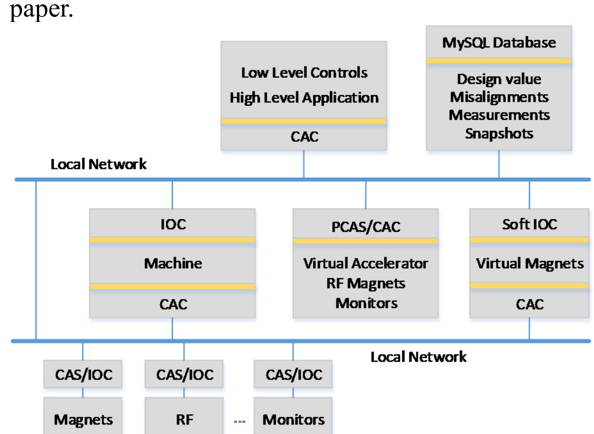

Figure 1: Schematic layout of EPICS control system and high-level controls based on Open XAL for XiPAF.

DATABASE SCHEMA

Database is necessary for commission and operation of an accelerator. Database server of XiPAF is constructed with MySQL. An adaptor for JDBC library of MySQL is necessary to achieve access with program interfaces in XAL. Considering that there are several operation scenarios for XiPAF and each scenario is associated with a set of design values, scenario management is the key of database schema. The ER diagram is shown in Fig. 2. All design values including set points of accelerator nodes, ramping curves of synchrotron devices, and B-I curves of electro-magnets will be organized and indexed with a foreign key named "SCENARIO_ID". All devices are indexed with a primary key named "DVC_ID". Additional tables are needed to store specific properties of a certain type of devices, such as "mag_dvc", "rf_dvc" and "bpm_dvc" [3].

We also modified db2xal application to accommodate our database schema and generate XAL lattice file automatically. A screen snapshot of modified db2xal application is shown in Fig. 3. Users can choose operation scenarios and sequences as they want.

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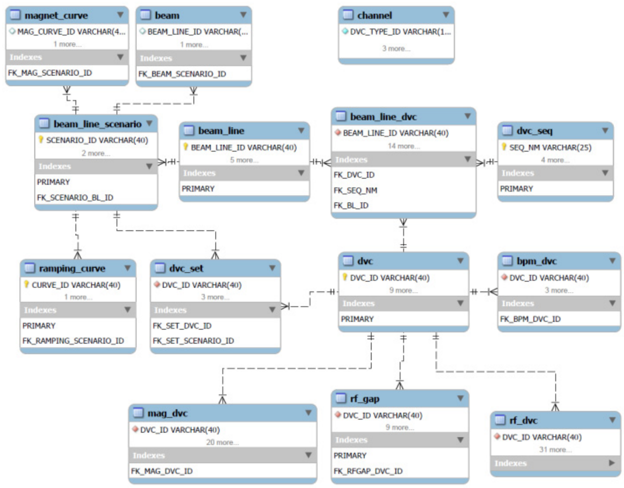

Figure 2: ER diagram of database schema for XiPAF.

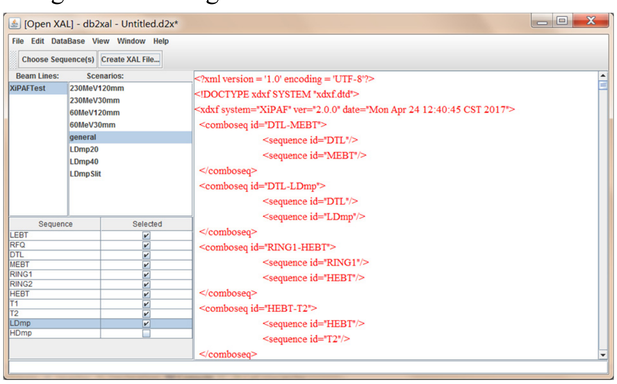

Figure 3: Screen snapshot of modified db2xal application.

VIRTUAL ACCELERATOR

As shown in Fig. 1, virtual accelerator of XiPAF is configured as a PACS as well as a CAC parallel with IOC of EPICS control system. Figure 4 shows the schematic view of virtual accelerator for XiPAF. It consists of three main components, namely parameter synchronizer, online model and a PCAS. Parameter synchronizer provides multi-way to generate an online model dynamically. Online model for XiPAF can be synchronized with three types of data sources, among them, design parameters and historical parameters are stored in database, and live parameters are stored in IOCs. All process variables (PV) of interest are stored in PCAS, and can be accessed through network.

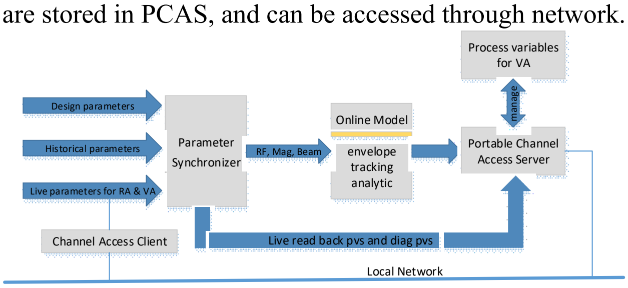

Figure 4: Schematic view of virtual accelerator for XiPAF.

Original virtual accelerator in Open XAL serves as a debugging tool for high-level applications. We are going to make it more powerful, so that it can be configured to run at three modes to achieve different functions [4]. All modes and functions are list as below.

- Debugging mode: Offline debugging tool for high-level applications.
- Test mode: Offline test tool for OPIs as well as parameter test bed for commission.
- Diagnostic mode: Virtual diagnostics for beam.

Mode configuration is implemented with different synchronizers and two sets of PV names for real accelerator (RA) and virtual accelerator. As for debugging mode, VA synchronizes parameters with design values or historical values stored in database, and updates diagnostic PVs in PACS.

VA can be used to perform an offline test for OPIs, in this case, VA accepts parameters received from OPIs, and acts like a real machine when we perform actions on OPIs. Test mode is also helpful for commission and operation training. We can test a set of parameters in VA before applying them to RA.

If the online model in VA is optimized to match RA, VA can be served as virtual diagnostics for beam. In this mode, parameters are synchronized with IOCs of RA. We can get all information of beam in any position we want with online model. For the sake of security, PV names in VA and RA should be different, and VA cannot have write access to IOCs of RA.

HIGH-LEVEL APPLICATION

Energy Ramping

Energy ramping is a critical process of synchrotron operation. in order to get a better understand of this process and prepare for commission work in the future, a model changing with time is necessary. Time-dependent nodes and a set of related classes are integrated into online model of XiPAF, so that we can simulate energy ramping process of synchrotron. This is meaningful for commission of synchrotron, especially for the commission of MA loaded cavities. Class diagram of classes related to ramping simulation is shown in Fig. 5. Three types of time-dependent nodes are considered, that is quadrupole, wedge dipole and RF gap. All information of ramping curve is stored in subclass of “WaveForm”. There are two modes for ramping simulation, one is “propagate_everyturn”, and the other is “propagate_everynode”. All parameters of time-dependent nodes are updated every turn for the former, and every node according to time of arrival for the latter.

A simulation of single particle tracking is performed to check the correctness of time-dependent nodes and ramping curve. Simulation results are shown in Fig. 6. Acceleration time up to nominal energy of 230 MeV is 490 ms, during which the particle is tracked about 1.56×10^{6} turns. Coordinates and energy of the particle are recorded every 1000 turns. Therefore, what we can see from Fig. 6 is synchrotron motion of the particle, and the oscillation frequency obtained from simulation matches analytic synchrotron tune. Energy ramping curve reaches nominal

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energy of 230 MeV after 490-millisecond-long acceleration in the ring, just the same as what we expect.

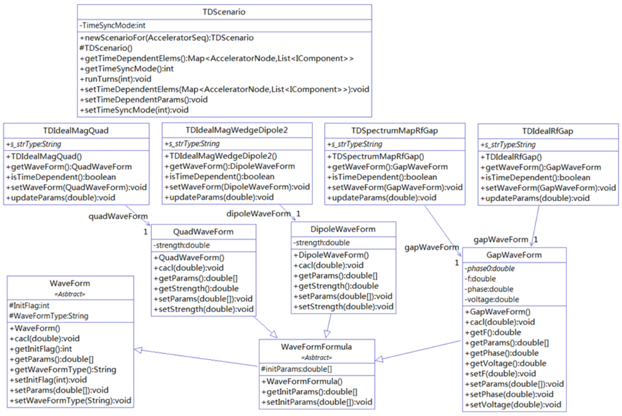

Figure 5: Class diagram of classes related to ramping simulation.

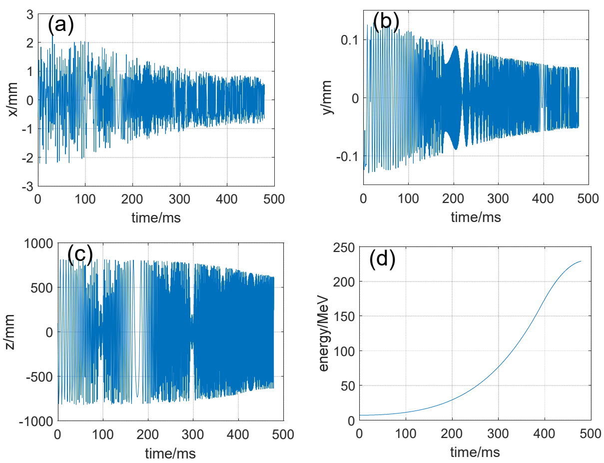

Figure 6: Simulation results of single particle tracking with time-dependent nodes. (a), (b) and (c) Horizontal, vertical and longitudinal coordinates of the particle every 1000 turns. (d) Energy ramping curve.

High-level Application

High-level applications for XiPAF are under development. Applications used for commission of XiPAF are list as below.

- Energy meter.
- RF set-up for DTL.
- RF set-up for Debuncher.
- Trajectory correction and difference.
- Beam parameters measurement for Beam Line.
- Dispersion and ORM Measurement for Beam Line.
- BBA for Beam Line.
- Closed orbit display and correction.
- BBA for Ring.
- Tune scan and monitor.
- Optics measurement for Ring.
- Beam at foil and injection control.

There are tens of applications in Open XAL project, some of which may fulfil our requirements, such as Ema for Energy meter, Pasta for RF set-up for DTL. However, we cannot use them directly unless machine-specific modifications are made. Other applications such as energy spread measurement, BBA for ring and beamline, should be developed by ourselves. Here we just make a sample show of high-level applications we are developing.

Figure 7 shows a program named envelope fit, which can process measurements of profile monitors and make an optimization of twiss parameters so that measurements match simulation results as much as possible. Figure 8 is a screen snapshot of RF set-up for debuncher, we perform a 2D scan on RF amplitude and magnetic field of a bending magnet, and finally we get a curve of energy spread vs. RF amplitude. With this curve, optimal RF set point of debuncher can be determined.

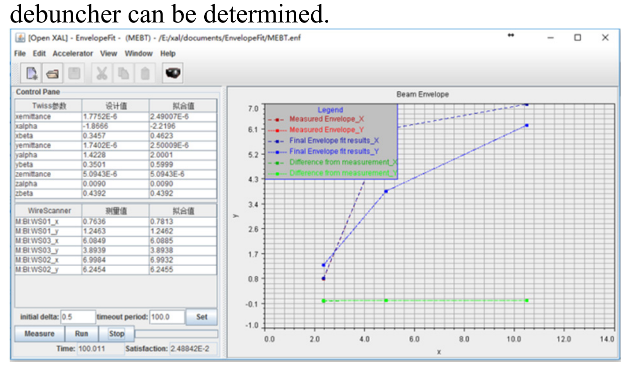

Figure 7: Screen snapshot of envelope fit application.

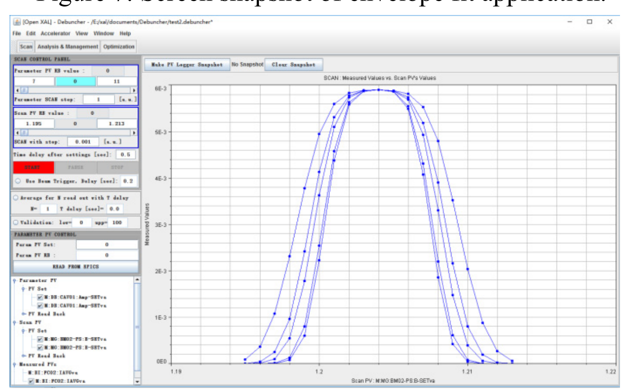

Figure 8: Screen snapshot of RF set-up for debuncher.

CONCLUSION

We are developing commissioning tools for Xi'an Proton Application Facility based on Open XAL. This paper introduces the work we have done to adopt Open XAL in XiPAF project. We have developed a database server for test, and will be integrated with control system database in the future. Operation modes of virtual accelerator and the way to integrate it with control system has been studied. In addition, a more accurate model of element errors will added into virtual accelerator in the future. Time-dependent nodes are integrated into online model, and high-level applications are under development and will be completed by the end of this year.

REFERENCES

[1] Zheng S X., Design of the 230MeV proton accelerator for Xi'an Proton Application Facility[C], In *Proc. HB2016*, Sweden, paper MOPR006

[2] https://openxal.github.io/.

[3] WANG Peng-Fei, CAO Jian-She, YE Qiang., Development of ADS virtual accelerator based on XAL[J], in *Chinese Phys-ics C*,2014,(07):129-132.

[4] D. Uriot, "The virtual accelerator concept", EU-CARD2/MAX Accelerators for Accelerator Driven Systems Workshop, CERN, March 2014. Contribution 13: https://indico.cern.ch/event/300409/contributions/1663610/attachments/565904/779596/Max_eucard2_uriot.pdf