BEAM DIAGNOSTICS GLOBAL DATA WAREHOUSE IMPLEMENTATION AND APPLICATION AT SSRF *

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Abstract

A fully functional beam diagnostics system has been developed at SSRF serving user operation and machine study since 2009. Global orbit disturbances, BPM failures and DCCT noise signal have been observed randomly. Without correct event trigger it is hard to capture real time data and analyze the cause of the above failures. A BI global data warehouse has been implemented as a solution to buffer online data and do correlation analyze at SSRF.

INTRODUCTION

More than 200 diagnostics devices including BPMs, current transformers, beam size monitors, filling pattern monitor and bunch length monitor are employed to deliver beam and machine information for operators and accelerator physicists at SSRF[1]. More than 20k scalar process variables and hundreds of 2k-points waveform records are published online per second. With proper analyze tool-kits this data could be invaluable. Otherwise the potential of new electronics will be wasted and bunches of running data could become the junk haunting in the control network.

On the other hand several kinds of hardware and software failures have been recorded during past two years. The reliability and usability of diagnostics data are damaged by these failures. The most critical failures include:

- BPM cables connection broken accidentally during system maintenance period.
- Global orbit disturbance.
- Random glitch and offset jump of individual BPM readings.
- Burst noise of DCCT readings.
- Large measurement error of filling pattern monitor due to orbit disturbance.

There are no tools ready yet to alarm operators before failures occurring or to do trouble shooting after it happened. The regular achieved data, which sampling rate is 1Hz typically, is not good enough for this purpose. History of broad band data such as turn-by-turn (694 kHz sampling rate typically) BPM data or raw DCCT waveform (10k sampling rate typically) is required in this case. Achieving broad band data every second is impossible due to huge data size. Building a global beam diagnostics data warehouse to do online correlation analyzing and save qualified trouble shooting data is a better solution.

The data warehouse needs to deliver the following functionalities:

- Provide a set of online inspection tool-kits to do self-check for beam diagnostics system. All hardware connections and electronics configurations can be verified quickly with these tool-kits.
- Generate proper event triggers for hardware and software failures. Trouble shooting data including broad band waveform can be saved correctly for offline analyze with these triggers.
- Maintain a dynamic trust list of BPMs for orbit feedback system and machine study. Orbit feedback system or other applications can determine which BPM need to be kept of the loop.
- Install a healthy flag of machine. The information of reliability and stability of whole machine could be integrated into this flag.
- Assign a confidence flag for each diagnostics device. Consumers can decide to adopt or drop acquired data based on attached flag.

SYSTEM DESIGN

Based on above requirements a beam diagnostics global data warehouse, including six data analyze engines, a reference database, a history trouble shooting database, a running database, a confidence table and a high speed Matlab-EPICS interface, will be implemented part by part. The system architecture is shown in Figure 1.

Data Analyze Engine

Data analyze engines are core components. In the first stage six data analyze engines are implemented working together:

- Reference manager. Collecting regular history data to build a baseline for each device and whole machine. Setup references online based on reference database.
- BPM turn-by-turn analyzer. Building BPMs turn-by-turn data matrix for time domain and frequency domain correlation analyzes. Calculate confidence value for each BPM.
- BPM slow application analyzer. Monitoring global orbit and individual BPM performance at 1 Hz sampling rate. Calculate confidence value for each BPM.
- Beam current analyzer. Put average current data, filling pattern data and sum signals of all BPMs together to do correlation analyze. Calculate confidence values for DCCT, filling pattern monitor and each BPM.
- Beam size analyzer. Monitoring beam size change and compare with beam position spectrum data to calculate confidence value for interferometer or X-

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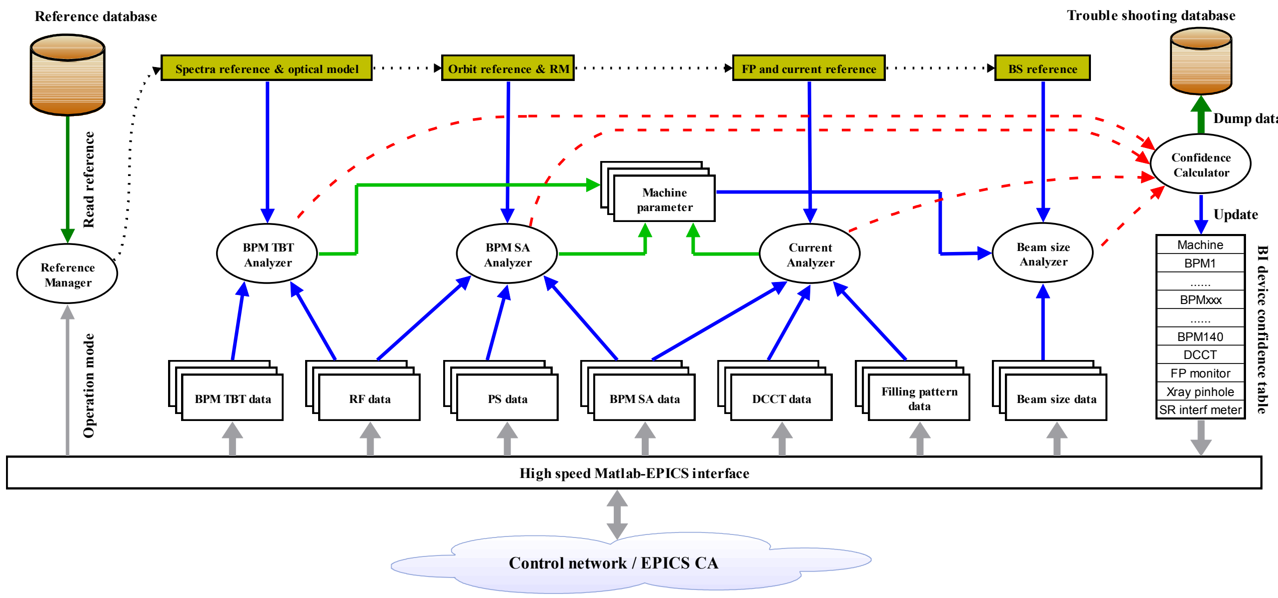

Figure 1: System architecture of BI global data warehouse.

ray pinhole camera. This engine is not implemented yet in the first stage.

- Confidence calculator. Collecting all other analyzing results together to generate the final confidence flag for each device and whole machine. Generate failure event trigger to push running data into history database.

Reference Database

Reference database contains baseline data for each diagnostics device and for whole machine. It is derived from previous running data. For every operation mode an individual baseline is needed to be built.

Running Database

Running database is a summary of fresh diagnostics data retrieved from control network. There are two circular buffers online.

The first buffer is 100 seconds long with 1 Hz sampling rate. Each frame of this buffer contains the following components:

- All BPMs close orbit data (BW 5 Hz).
- All BPMs small size turn-by-turn data (2048-points waveform each, BW 397 kHz) for devices performance evaluation.
- DCCT raw waveform (BW 5 kHz) and average value (BW 1 Hz)
- Filling pattern data (BW 1 Hz)
- Dedicated BPM large size turn-by-turn data (20k-points waveform, BW 397 kHz) for beam performance evaluation.

The data in this buffer is used to do online analyze. When failure occurs this buffer will be frozen and push into trouble shooting database.

The second buffer is 24 hours long with 0.01Hz sampling rate. The data structure of each frame is same as the first one but the band width of each component is narrowed down to 0.005Hz. This buffer will be saved every day as a regular achievement for long term performance evaluation.

Data Confidence Table

Data confidence table contain the performance evaluation results for each diagnostics device and whole machine. It will be published and updated as a EPICS PV through control network at 1 Hz. Consumers can get this information online and decide to use corresponding data or drop it.

History Trouble Shooting Database

The component of history trouble shooting database comes from running database. Each record is link to a failure event. More precise analyze can be done manually with this database to locate the failure source.

High Speed Matlab-EPICS Interface

In the first stage all applications are build on Matlab platform. A high speed Matlab-EPICS interface faster than LCA or MCA is required. Following the idea of Shared Memory IOCcore interface for LabVIEW a similar software package has been developed[2].

IMPLEMENTATION & APPLICATION

The running database and reference database were built at last summer. The data analyze engines were added into the system one by one after that. BPM TBT, BPM SA and current analyzer are running routinely for now. But reference manager and data confidence calculator is not fully functional yet. More history data need to be accumulated to build baseline for different operation mode. More accurate algorithm and threshold need to be defined.

Even so the preliminary applications already showed the great potential for diagnostics engineers, machine operators and accelerator physicists.

After summer maintenance, which included BPM cables replacement and electronics upgrade, the BPM TBT analyzer was used to verify the quality of cable connection and electronics configuration. FFT method is the easiest way to do this. Figure 2 shows the horizontal position spectra summary of all BPMs. The bad cable connections of BPM # 15 and #68 were located immediately in this way.

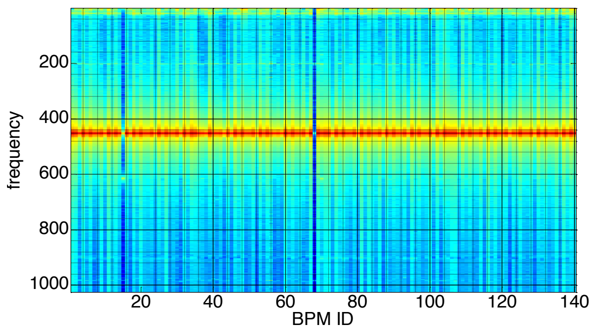

Figure 2: Horizontal position spectra of all BPMs. It shows BPM #15 and #68 different.

Another method, model independent analyze (MIA)[3], is also adopted into BPM TBT analyzer. Samples during injection are used in this case. Figure 3 shows a typical result of temporal vectors. Betatron oscillation, energy oscillation mode and electronics noise mode are easily retrieved from raw matrix. The corresponding amplitude distributions (spatial vectors) of these oscillations can be used to evaluate the performance of BPMs or locate the noise source.

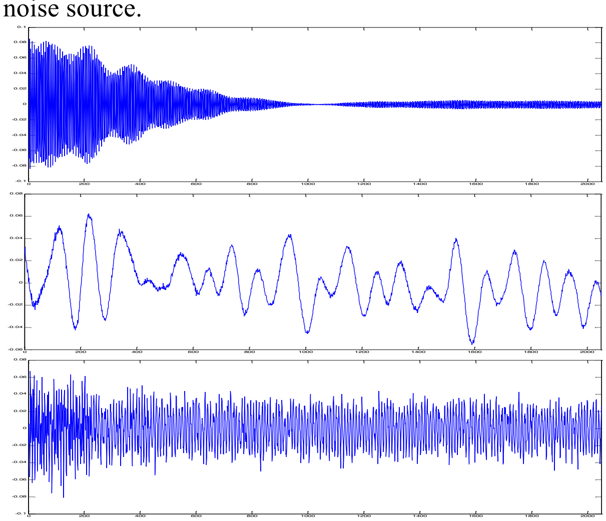

Figure 3: Betatron oscillation mode (top), energy oscillation mode (middle) and 68 kHz global electronics noise mode (bottom) retrieved from BPM TBT matrix using MIA method.

With BPM SA analyzer and trouble shooting database the orbit interlock event is much easier to be confirmed. Figure 4 shows a set of history data captured by BPM SA analyzer just before beam lost. A global orbit glitch was clearly recorded to be a hard evidence of orbit interlock.

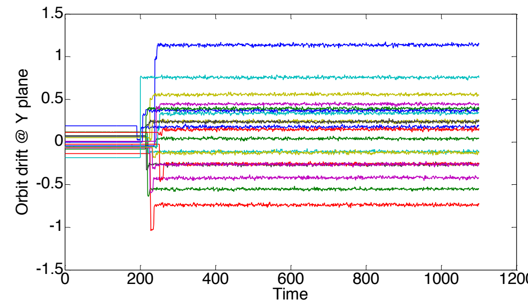

Figure 4: Global orbit glitch occurred just before beam lost. This achieved data confirms orbit interlock event.

The main purpose of current analyzer is used to evaluate the performance of DCCT and filling pattern monitor. Meantime the operation qualities also can be recorded by this tool. Figure 5 shows filling patterns of 4 different runs. The repeatability is not good enough due to manually injection procedure. The automatic filling pattern control and feedback is definitely needed in the future.

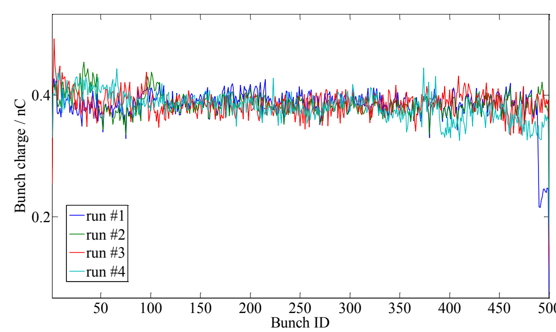

Figure 5: Repeatability of filling pattern recorded by current analyzer.

CONCLUSTION

A global beam diagnostics data warehouse has been implemented at SSRF. BPM TBT, BPM SA and current correlation analyzer are online. Preliminary applications show the great potential for all users. More functionality will be integrated in the future.

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