ISBN: 978-3-95450-250-9 ISSN: 2673-5520 doi:10.18429/JACoW-MEDSI2023-TUPYP053

CURRENT STATUS OF VIBRATION MONITORING SYSTEM AT SOLARIS

M. Piszak*, SOLARIS National Synchrotron Radiation Centre, Cracow, Poland

Abstract

Solaris synchrotron radiation centre, despite being relatively new facility, began enlargement of its experimental hall in 2022 in order to accommodate new beamlines. The construction works were carried out along with regular accelerators and beamlines operation and generated high levels of vibration. To better understand the influence of vibrations on electron and x-ray beams' stability, an accelerometer-based monitoring system was designed and implemented. The system consists of a triaxial measurement point equipped with seismic accelerometers located on bending magnet inside storage ring and a central signal conditioning and acquisition point. The results of long-term vibration data collection and analysis will be presented along with plans for the future system development.

INTRODUCTION

Low vibration environment is crucial for an optimal operation of storage rings and beamlines at synchrotron light sources. Evaluation of background vibrations in synchrotron facilities is typically carried out using accelerometers in short-term survey measurement campaigns [1]. Some facilities decide on permanent monitoring systems installation [2]. The Vibration Monitoring System (VMS) at SOLARIS synchrotron radiation centre has been developed in order to provide continuous diagnostic data of vibration conditions in the storage ring.

The VMS started operation in the beginning of 2023 and the commissioning period ended in September 2023 (due to long component delivery schedules). Along with the development of the system, the enlargement of the experimental hall and related construction works were carried out. The VMS has played an important role during accelerators and beamlines operation coinciding with heavy construction equipment works that generated high levels of vibrations. When established vibration limits were exceeded, actions were taken: the problematic construction methods were changed to lower the impact of vibrations; the activities were rescheduled to take place during less-critical time periods.

SYSTEM DESIGN

Hardware

Currently, the VMS consists of a single Measurement Point (MP) located inside the storage ring on Double-Bend Achromat (DBA) cell in section 01. Measurement point consists of three PCB Piezotronics Model 393B31 seismic accelerometers (nominal sensitivity: $1\,\mathrm{V\,m^{-1}\,s^{2}}$, frequency range: 0.1 Hz to 200 Hz). Transducers are fixed to a custom-build, triaxial adapter that allows for axial alignment with respect to the DBA cell. The MP's orientation was chosen accordingly: the x-axis of the MP is normal to the electron beam at the DBA center, the y-axis is tangential to the beam and the z-axis is oriented vertically (Fig. 1).

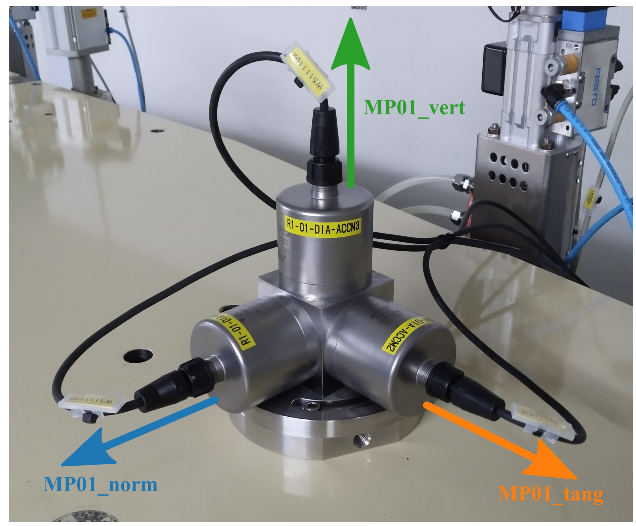

Figure 1: Triaxial measurement point with custom adapter mounted on the top surface of a DBA cell.

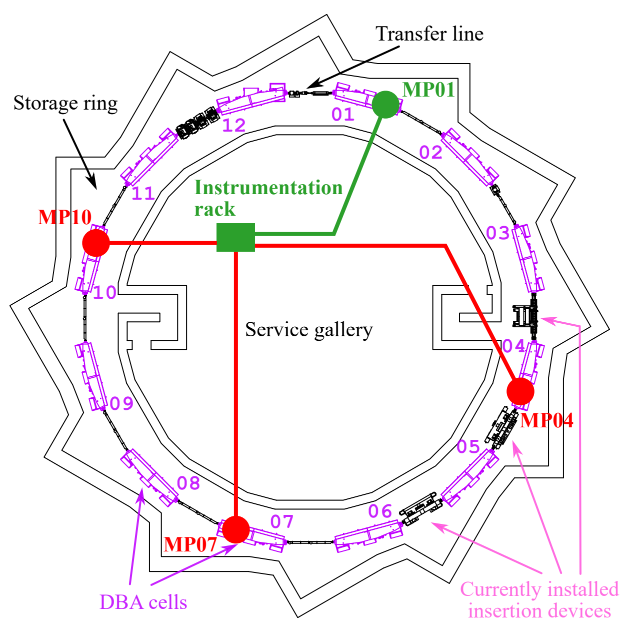

Figure 2: VMS arrangement view over the storage ring area (green color indicates existing infrastructure; red color indicates planned measurement points).

* marcel.piszak@uj.edu.pl

ISBN: 978-3-95450-250-9 ISSN: 2673-5520 doi:10.18429/JACoW-MEDSI2023-TUPYP053

Analog IEPE signals from accelerometers run to the central acquisition point of the system located in a rack cabinet in the service gallery area (Fig. 2).

The central point consists of PCB Piezotronics Model 483C50 signal conditioner (8-channel, gain: ×0.1 to ×200), NI cDAQ-9185 chassis and a single NI 9239 CompactDAQ voltage input module (4-channel, 24-bit, input range: ±10 V). Network data streaming is provided by the Chassis via Ethernet LAN connection. Conditioner is also connected to the same network, providing remote configuration and control possibilities. The system has a dedicated server for data acquisition, processing and logging. The VMS has a modular design, allowing for expansion of up to 16 channels with a single chassis configuration (Fig. 3).

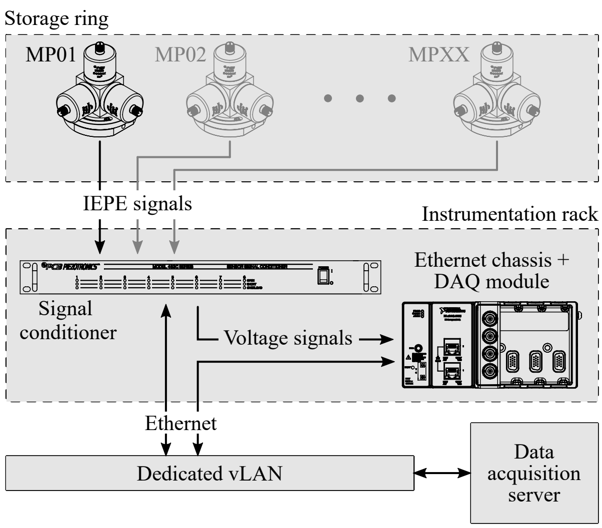

Figure 3: VMS schematic view.

Software

Data streamed by the DAQ hardware is routed to the server running a Windows virtual machine. Control software was developed in-house using LabVIEW programming environment. The software provides data acquisition, preprocessing and logging as well as system configuration and basic real-time analysis capabilities. In order to fully utilize the input range of the DAQ module, a programmable gain on the signal conditioner was set to ×100. The system's sampling frequency was set to 2 kHz. The software performs bandpass filtering (1 Hz to 300 Hz) and single integration to obtain velocity from acceleration. Then, the root-mean-square value is calculated and averaged over 10 s windows. Processed data is being continuously logged using TDMS file format. Other available real-time analysis options are: displacement PSD and third-octave spectra views (Fig. 4). Software has the ability to log complete data waveforms on-demand or using preset time schedule.

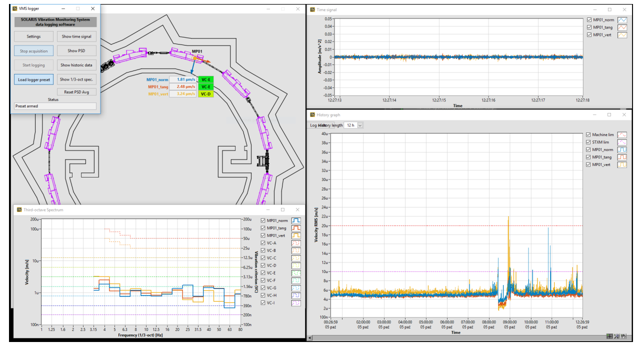

Figure 4: Control software GUI.

MEASUREMENTS AND ANALYSIS

Time Domain Analysis

The final installation of MP01 was completed in July 2023 and the process of data acquisition and archiving started. The construction works related to experimental hall enlargement were ongoing and involved heavy equipment operation. The accelerators' shutdown period finished in the end of August 2023 and some construction works overlapped with the operation of accelerators. Sample time history presenting RMS vibration velocity (10 s averaged) can be seen in Fig. 5. During normal storage ring operation, a stable level of 4 $\mu m\,s^{-1}$ to 6 $\mu m\,s^{-1}$ is observed in all three axes. During shutdown, levels as low as 1.2 $\mu m\,s^{-1}$ can be observed (in vertical direction). Contributions from construction works were as high as 80 $\mu m\,s^{-1}$. The maximum allowed value for storage ring operation in any direction was set to 20 $\mu m\,s^{-1}$. Construction works were either rescheduled or modified when vibrations exceeded limit for a prolonged time.

Frequency Domain Analysis

Short-term time series of acceleration signals during various operating conditions were recorded for further frequency analysis. Power spectral densities were calculated and resulting spectra were integrated to obtain displacement information. Figure 6a represents PSD averaged using Welch's method [3] from 1-hour long waveform obtained during normal operation of the storage ring. Visible peak at approx. 26 Hz is corresponding to 1st mode of DBA cell on concrete supports. Results of finite element modal analysis (Fig. 7) indicates that the biggest directional magnitude of 1st DBA cell mode is corresponding to the MP01 normal axis.

The difference of RMS velocity levels between shutdown and operation was further investigated. The influence of DBA cell's magnet cooling system is believed to be the main cause of increased vibrations. Water flowing through ducts in magnet coils generate broadband vibrations that propagate throughout DBA body. Increased energy in frequency band up to 45 Hz can be seen in Fig. 6b.

CONCLUSION

The VMS system at SOLARIS was build and commissioned with success. Despite relatively short operation time,

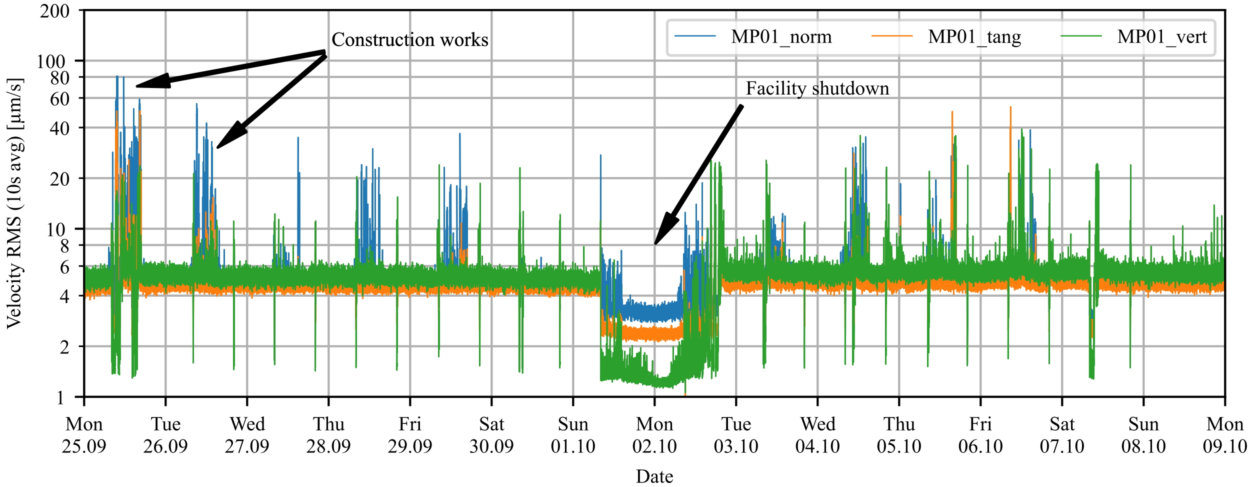

Figure 5: RMS vibration velocity time history spanning 2 week period.

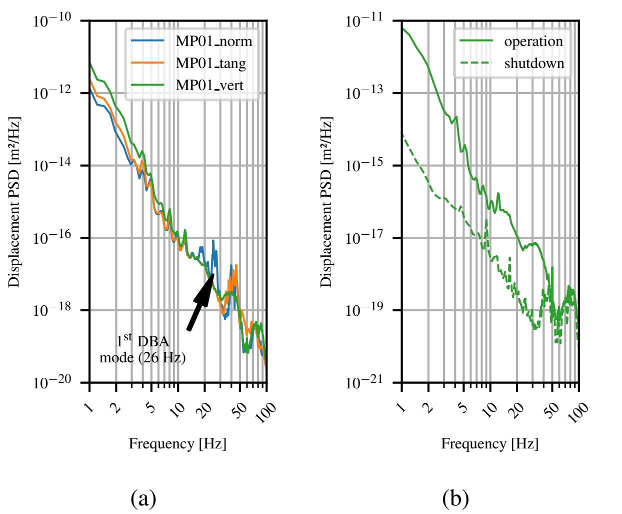

Figure 6: Displacement PSD of (a) all axes during operation and (b) vertical direction during shutdown vs. operation.

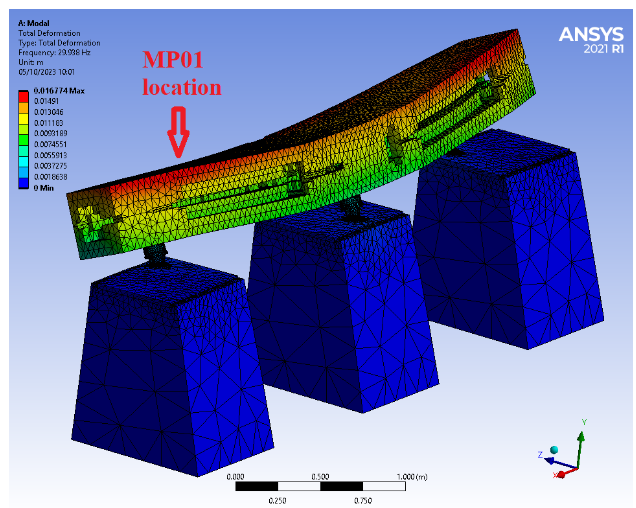

Figure 7: Results of modal FEA showing 1st mode (30 Hz) of DBA cell on supporting structures.

data gathered by the system proved to be useful during construction works.

The system is planned to be expanded with two or three additional measurement points distributed across remaining DBA cells in order to provide more information about the mechanical dynamics of the storage ring. Obtained data is planned to be correlated with electron beam parameters as a part of a greater study on beam stability at SOLARIS. Plans for the future also include new software development with integration to the Tango control system of the synchrotron facility.

ACKNOWLEDGEMENTS

The work is supported under the Polish Ministry and Higher Education project: "Support for research and development with the use of research infrastructure of the National Synchrotron Radiation Centre SOLARIS" under contract nr 1/SOL/2021/2.

REFERENCES

[1] K. Haga *et al.*, "The Vibration Measurements at the Photon Factory Storage Ring Building," in *Proc. EPAC'00*, Vienna, Austria, Aug. 2000, pp. 2388–2390. `https://jacow.org/e00/papers/TUP4A11.pdf`

[2] K. H. Hsu, C. K. Kuan, W. Y. Lai, and H. S. Wang, "Vibration Monitoring at TPS Storage Ring," in *Proc. MEDSI'18*, Paris, France, Jun. 2018, pp. 227–230. `doi:10.18429/JACoW-MEDSI2018-WEPH13`

[3] P. Welch, "The use of fast fourier transform for the estimation of power spectra: A method based on time averaging over short, modified periodograms," *IEEE Trans. Audio Electroacoust.*, vol. 15, no. 2, pp. 70–73, 1967. `doi:10.1109/TAU.1967.1161901`